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Effects of Weather on the Forest Tent Caterpillar *Malacosoma disstria* Hbn., in Central Canada in the Spring of 1953[1]

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Introduction

Sweetman (1940) suggested that unfavourable spring weather is probably the most important natural check for the forest tent caterpillar, *Malacosoma disstria* Hbn. He observed that warm weather in April or early May that induces hatching, followed by a week or more of cool weather, frequently destroys the caterpillars. Blackman (1918), Tomlinson (1938), and Hodson (1941) have reported similar observations.

An increase in the number of forest tent caterpillars in northwestern Ontario, first noticed in 1948, indicated a large-scale outbreak of this insect to be imminent. By 1949, defoliation of trembling aspen, *Populus tremuloides* Michx., was apparent in several localities. In 1950, 1951, and 1952, populations increased tremendously, and each year the infestation area increased by several thousand square miles. Small local infestations first appeared in southeastern Manitoba in 1951, and in the following year, these were consolidated into an area of general infestation continuous with that in Ontario. Egg surveys in the fall of 1952 indicated that populations would again be high in 1953 throughout most of this territory. However, weather conditions in the spring of 1953 brought an end to the infestation over a large part of its range. It was possible to observe these events critically from the Cedar Lake Field Station in the Sioux Lookout District in northwestern Ontario, and, simultaneously, observations were made at many other points throughout the area by forest biology rangers.

The unusual weather conditions in 1953 affected forest tent caterpillar populations in other areas extending through northeastern Ontario, northern Quebec, and parts of Minnesota. However the reduction in population levels in these areas was, for the most part, not as great as in the area dealt with here.

Observations at Cedar Lake

Defoliation by the caterpillars became apparent in the immediate vicinity of Cedar Lake in 1951, and, by 1952, populations had increased sufficiently to cause from 50 to 75 per cent defoliation of most trembling aspen stands. In the spring of 1953, 339 and 389 egg bands were counted on two trembling aspen trees each measuring 10 inches in diameter at breast height. These counts indicated a potential larval population more than capable of completely defoliating the trees.

Unusually high temperatures were recorded in early May 1953, the average daily maximum temperature at Cedar Lake from May 3 to May 9 being 78°F. (Table 1). Tent caterpillar hatching began on May 6 and hatch records from 146 egg bands indicated that 85 per cent of the total larval hatch had occurred by May 9. The opening of the buds on trembling aspen coincided with the first appearance of the caterpillars.

Strong northeasterly winds began to blow by mid-day on May 10 and continued with gusts up to 40 miles an hour throughout the night. Snow and fine hail started to fall about midnight and continued till morning. The temperature fell to a minimum of 24°F. on the 11th and failed to surpass 29°F. through-

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out the rest of the day. On the afternoon of May 11, examination of branches revealed the small larvae to be clustered on the leeward side of the branches and egg bands. A number of branches were transferred to the field laboratory, and warmed to room temperature. Larval activity soon commenced and a count showed that approximately 10 per cent of the larvae were dead.

The wind abated during the evening of May 11. The temperature dropped to 22°F. by the morning of May 12, and failed to exceed 37°F. during the rest of the day. Branches carrying larvae were again brought to room temperature. By this time larval mortality had reached 50 per cent. On May 13, a minimum of 30°F. was recorded marking the last spring frost of 1953 at Cedar Lake. Counts on branches again showed that 50 per cent of the insects were dead. This, however, does not give a true estimate of mortality, because dead larvae had fallen, or been blown, to the ground. These larvae could be readily detected on the snow, and it was estimated that there were between 15 and 20 larvae per square foot of ground surface in one stand of young aspen. The ratio of larvae (dead and alive) left on the branches to the number of hatched eggs approximated one to nine. Therefore it appears that, in three days, the storm and the freezing temperatures had killed some 95 per cent of the hatched larvae.

Generally, both leaves and shoots of trembling aspen were completely destroyed. In a few cases, however, only the newly-opened leaves were killed and shoot growth resumed a few days later. Consequently, after the frost many trees were devoid of foliage until releafing began about a month later from adventitious buds on branches and even on the main trunks.

The larvae that survived the cold and those that hatched later starved for lack of proper food. In spite of diligent searching, only two fifth-instar larvae and one adult were found in the Cedar Lake area during the course of the summer. Moreover, subsequent examination of trembling aspen in the fall failed to yield any egg bands.

Observations Throughout the Infestation Area

Fig. 1 shows the area covered by the forest tent caterpillar infestation in Central Canada in 1952. The infestation extended from Sandilands Forest Reserve,

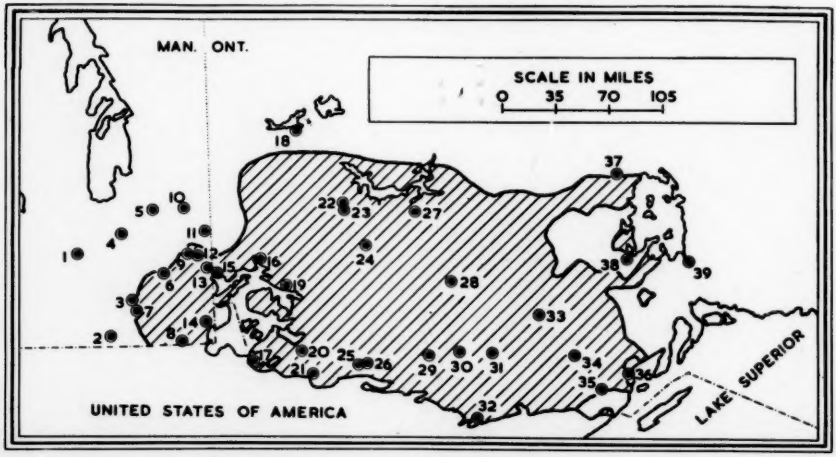

Fig. 1—Map showing medium-to-heavy infestation of forest tent caterpillar in central Canada, summer 1952. Numbered localities indicate specific weather and tent caterpillar observation points (see Tables I, II and III).

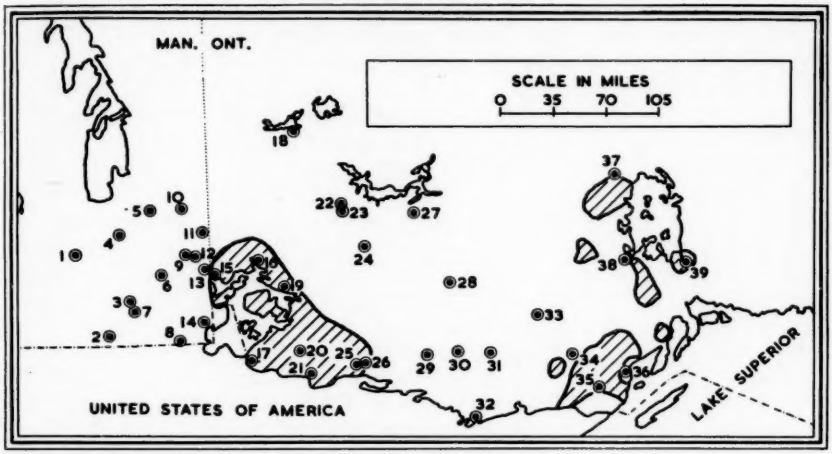

Fig. 2—Map showing medium-to-heavy infestation of forest tent caterpillar in central Canada, summer 1953, following adverse spring weather. Numbered locations indicate specific weather and tent caterpillar observation points (see Tables I, II and III).

Manitoba, in the west to Lake Nipigon in the east. The most northerly boundary was marked by Red Lake and Armstrong. To the south the infestation continued into northern Minnesota. In central Canada, trembling aspen stands throughout an area of some 43,000 square miles were affected, with about 90 per cent of the area in Ontario, and the remainder in Manitoba. Fig. 2 shows the areas in central Canada where forest tent caterpillar infestations persisted in 1953 after the spring catastrophe. By the autumn of 1953, less than one-sixth of the 1952 infestation area sustained high populations of caterpillars. In 1952 and 1953 the areas of infestation were determined through aerial surveys and through general ground checks. The specific observation points shown in Figs. 1 and 2 indicate localities from which weather records, tent caterpillar egg band counts, and hatch-records were obtained. From some of these localities all three types of records were obtained while from others only one or two types were obtained (see Tables I, II, and III).

Egg band counts were made in the fall of 1953 at 33 localities on two to four trembling aspen trees averaging 2 to 6 inches in diameter (Fig. 1 and Table II). Although populations were on a downward trend in a few localities where the infestation had been active over a number of years, the 1952 counts had indicated that, over most of the area, large numbers of insects were again to be expected in 1953. The number of egg bands, however, was greatly reduced by the fall of 1953. In Ontario, the average number of egg bands for 18 localities was 72 in the fall of 1952, and for 20 localities (including 17 of those studied in 1952) only three in the fall of 1953. In Manitoba, although numbers were generally smaller, the ratio of reduction was about the same.

It can be shown that failure of eggs to hatch did not contribute to the observed decline in population levels in 1953. Table III gives the average number of eggs per band and the average percentage of hatch for ten egg bands from each of 18 localities for 1952 and 1953. In Manitoba, the lower average hatch (about 10 per cent) in 1953 than in 1952, was attributable to an increase in egg parasitism. This in any case was offset by the greater number of eggs per band. In Ontario, the average percentage of hatch was generally as good in 1953 as in 1952, or better.

TABLE I

Maximum and Minimum Temperatures (Fahrenheit) from May 4 to May 16, 1953, for a Number of Representative Localities in Central Canada.

Date	Winnipeg (1)*		Kenora (16)		Emo (21)		Cedar Lake (23)		Ignace (28)		Atikokan (30)		Ft. William (36)		Armstrong (37)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
May 4	68	32	64	39	67	27	66	32	55	29	68	25	63	27	61	23
" 5	79	42	76	41	75	25	74	38	71	30	73	25	75	29	72	28
" 6	88	50	81	50	84	30	82	53	79	35	82	30	81	35	71	29
" 7	92	51	89	53	88	40	89	56	71	52	89	49	87	35	77	34
" 8	88	52	82	54	86	43	85	53	85	56	88	42	90	38	81	34
" 9	74	58	78	55	82	40	81	44	71	54	85	40	85	45	85	34
" 10	62	42	60	35	62	58	42	32	57	31	75	43	60	42	36	24
" 11	36	29	29	26	38	33	29	24	27	21	60	28	36	31	23	19
" 12	40	25	37	21	38	19	37	22	36	19	34	20	35	24	31	14
" 13	57	25	53	26	43	19	51	30	50	35	52	20	52	21	47	19
" 14	57	34	52	36	56	32	52	39	47	38	57	21	55	24	55	32
" 15	48	31	51	35	50	38	53	40	50	38	50	35	53	35	55	27
" 16	65	32	56	31	61	26	59	36	57	37	62	37	58	39	60	34

*Reference Number Figures 1 and 2.

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Events as they occurred at Cedar Lake seem to have prevailed over the major part of the infestation area in northwestern Ontario. Table I gives the maximum and minimum temperatures from May 4 to May 16 for a number of representative localities. The actual larval mortality at the time of the cold spell no doubt varied with locality, depending on the weather conditions and the degree of larval hatch at the onset of the cold. However, starvation of any surviving or late-emerging larvae was inevitable over a large portion of northwestern Ontario, since the trembling aspen foliage was almost uniformly destroyed by the frost.

High population levels in Ontario persisted through the summer of 1953 mainly along the shores of the Lake of the Woods, Lake Superior, and Lake Nipigon. Near these large bodies of water both the insects and the foliage escaped to some degree because hatching was not complete and the aspen buds were not fully opened at the onset of the cold weather. Hatching at one locality in the vicinity of the Lake of the Woods and at another near Lake Superior was observed to begin on May 10, four days later than at Cedar Lake. This retardation apparently was caused by low night temperatures. The processes of larval

TABLE II

Average Number of Egg Bands per Tree in 1952 and 1953 for a Number of Localities in Central Canada

Location Reference Number[1]	Location	Average Number Egg Bands Per Tree	
		1952	1953
2	Stuartburn, Man.	1	0
3	Marchand, Man.	3	0
4	Beausejour, Man.	1	1
5	Lac du Bonnet, Man.	16	1
6	Hadashville, Man.	17	0
7	Sandilands, Man.	9	0
8	Sprague, Man.	10	0
9	Rennie, Man.	13	0
10	Pointe du Bois, Man.	5	0
11	Whiteshell Lake, Man.	13	0
12	Telford, Man.	42	1
13	Falcon Lake, Man.	25	1
14	Moose Lake, Man.	15	0
15	Ewart Township, Ont.	47	4
17	Wild Land Reserve, Ont.	133	8
18	Red Lake, Ont.	2	0
19	Devonshire Township, Ont.	–	3
20	Potts Township, Ont.	–	9
22	Jackfish Lake, Ont.	47	0
23	Cedar Lake, Ont.	364	0
24	Wainwright Township, Ont.	63	0
25	Watten Township, Ont.	–	11
26	Halkirk Township, Ont.	14	–
27	Vermilion Additional Tp., Ont.	24	0
28	Ignace Township, Ont.	1	0
29	Calm Lake, Ont.	42	0
31	Eva Lake, Ont.	2	0
32	Basswood Lake, Ont.	11	2
33	Upsala Township, Ont.	6	0
34	Conacher Township, Ont.	185	2
35	Gillies Township, Ont.	102	6
36	Fort William, Ont.	7	1
38	Poshkokagan River, Ont.	233	5
39	Orient Bay, Ont.	19	13

[1]See Figs. 1 and 2

emergence and of bud opening were arrested by the subsequent cold spell and were not resumed until some time later. Damage was sustained by some of the early-hatched larvae and by some of the developing foliage in these areas, and the residual level of tent caterpillar populations, though still in epidemic proportions, was considerably smaller than in the previous year (see Table II, localities 15, 17, 35, 36).

Farther west, in Manitoba, the mechanism of population decline was somewhat different. Even though most of the eggs had hatched before the onset of the cold, the data in Table IV show that relatively few larvae were killed directly by the cold. Furthermore, much of the trembling aspen foliage escaped injury, 25 per cent or less of the foliage being damaged over most of the outbreak area. The unfavourable weather conditions that persisted through May and early June were primarily responsible for the major reduction of larval populations in Manitoba. Only between 5 and 10 per cent of the original larval population remained by June 7 when the majority of the larvae were still in the third instar.

TABLE III

Average Number of Eggs per Band and Average Percentage of Hatch in 1952 and 1953 for a Number of Localities in Central Canada

Location Reference Number[1]	Location	Average Number of Eggs per Band		Average Percentage of Hatch	
		1952	1953	1952	1953
5	Lac du Bonnet, Man.	160	224	84	68
7	Sandilands, Man.	155	158	85	84
8	Sprague, Man.	137	156	94	82
9	Rennie, Man.	178	202	91	75
12	Telford, Man.	123	173	77	65
14	Moose Lake, Man.	170	181	91	81
22	Jackfish Lake, Ont.	126	153	75	88
24	Wainwright Township, Ont.	160	223	75	67
26	Halkirk Township, Ont.	138	204	93	92
27	Vermilion Additional Tp., Ont.	144	166	83	86
28	Ignace Township, Ont.	121	172	58	81
29	Calm Lake, Ont.	152	196	72	86
31	Eva Lake, Ont.	179	199	85	92
32	Basswood Lake, Ont.	148	185	92	87
33	Upsala Township, Ont.	177	181	77	86
35	Gillies Township, Ont.	176	168	95	82
38	Poshkokagan River, Ont.	165	191	62	87
39	Orient Bay, Ont.	228	191	79	91

[1]See Figs. 1 and 2.

TABLE IV

Average Percentage of Hatch of Egg Bands by May 10, and Average Percentage of Larvae Living on May 15, for a Number of Localities in Southeastern Manitoba

Location Reference Number [1]	Location	Average Percentage of Hatch by May 10	Average Percentage of Larvae Living on May 15
5	Lac du Bonnet	98	9
7	Sandilands	76	95
8	Sprague	80	95
9	Rennie	85	75
12	Telford	86	25
14	Moose Lake	70	90

[1]See Figs. 1 and 2.

This mortality is attributed to a prolonged period of unfavourable temperatures. Hodson (1941) has shown that at 60°F. second- and third-instar larvae develop very slowly and that fourth-instar larvae cease to develop and eventually die. Fig. 3 shows the daily maximum and minimum temperatures for Winnipeg from May 1 to June 12. From this it is evident that for a period of almost one month following the time of larval hatch, there were relatively few hours with temperatures above 60°F. Foliage development was not retarded to the same degree, and when temperatures favourable for larval feeding were again reached the

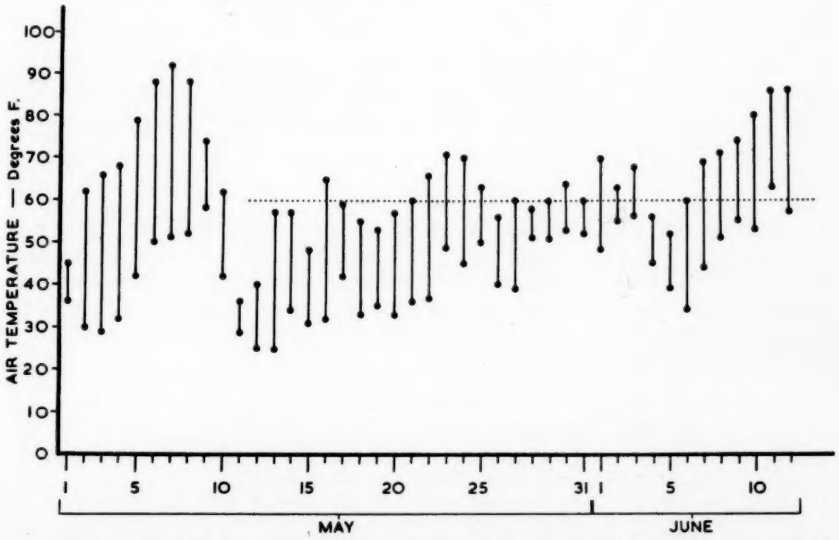

Fig. 3—Range of daily temperature from May 1 to June 12, 1953 for Winnipeg, Manitoba. The portion of the daily ranges above the dotted line through 60°F. indicates the relatively short periods of time satisfactory for early larval feeding and development. Hatching occurred just before May 10.

leaves were almost fully expanded and quite tough. In some localities, the larvae were found skeletonizing the leaves, eating the epidermal and mesophyll tissues, and avoiding the vascular tissue, a habit not characteristic of this species.

Parasites

The numbers of *Sarcophaga aldrichi* Parker, an important parasite of the tent caterpillar, had been increasing, and by 1952 had become very abundant. The records show, however, that for many sections of the area of infestation this parasite had not yet reached sufficient proportions to account for the sudden disappearance of the host (these data to appear in a future publication). Since these flies were not affected by the unseasonable weather, they were present in very large numbers in the summer of 1953, and contributed to further reduction of the tent caterpillar infestations in the area herein described.

Summary

Populations of the forest tent caterpillar that had reached epidemic proportions throughout an area of approximately 43,000 square miles in central Canada were drastically reduced over most of the area due to unusual weather conditions in the spring of 1953. Unseasonably high temperatures in early May caused the eggs to hatch and the trembling aspen foliage to open. The warm spell was followed by several days of freezing temperatures and snow, and by several weeks of cool, wet weather.

In northern Ontario, many of the young larvae succumbed at the time of the freezing temperatures, while many more died of starvation, since most of the trembling aspen foliage was destroyed by the frost.

Farther west, in Manitoba, fewer larvae were killed directly by the freezing temperatures, and the aspen foliage was not destroyed to the same degree. In this area, high larval mortality resulted from the prolonged cold and wet weather that followed hatching: only between 5 and 10 per cent of the larvae were still alive one month after hatching.

The parasite, *Sarcophaga aldrichi* Parker, which had been increasing in numbers during the previous few years in this region, was not affected by the unusual weather, and large numbers of this parasite caused further reduction of the residual tent caterpillar population.

Acknowledgments

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Bionomics of *Stethorus punctillum* Weise (Coleoptera: Coccinellidae) in Ontario[1]

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During a study of the effects of spray chemicals on the arthropod communities of peach orchards in the Niagara Peninsula, Ontario, begun in 1946, *Stethorus punctillum* Weise was found to be one of the more important predators of tetranychid mites. An investigation of its biology was undertaken in 1949 and continued through 1952. This paper presents chiefly the life-history, behaviour, and ecological aspects.

It was originally assumed that the native species *Stethorus punctum* (Lec.) was the one concerned, but specimens sent to Mr. W. J. Brown, Entomology Division, Ottawa, in 1949 were determined as of *S. punctillum* Weise—an Old-World species not previously recorded from North America. Among specimens of *Stethorus* spp. in the collection at the Vineland Station laboratory, all of those collected from 1916 to 1930 at Vineland, Jordan, and Grimsby were of *punctum*, whereas those collected in 1940 and later in the same area were of *punctillum*. From 1950 to 1953 several hundred males collected by the writer, largely from peach but also from apple, plum, cherry, and various other plants between Grimsby and Queenston, were of *punctillum* as indicated by the genitalia. A number were also taken in hibernation among debris in woodland. No specimens of *punctum* were found.

It seems remarkable that *punctillum* should replace *punctum* within a comparatively short period. Mr. Brown (in litt.) has suggested that *punctum* may not have been collected during the present investigations because it has different habitat preferences; however, some of the old Vineland specimens were collected on apple trees, and the literature contains many references to its common occurrence in orchards.

In North America, Mr. Brown (in litt.) stated that *punctillum* occurs in southern Ontario west to Leamington, north to Georgian Bay, and east to the Niagara Peninsula. Tonks (1953) collected it on Lulu Island, near Vancouver, B.C., in 1950. Dr. E. A. Chapin (in litt.), United States National Museum, Washington, reported it from two localities in Massachusetts, and Lathrop (1951) recorded it from Maine. According to Kapur (1948) it is widely distributed in the Palearctic region from western Europe to Japan.

S. punctum and *punctillum* can be separated only by the internal genitalia, described by Brown (1950).

Collyer (1953) gave an account of the biology of *S. punctillum* in England.

General Methods

Insectary and Laboratory Studies.—The life-history was studied mainly in a screened insectary. The insects were individually confined in ⅜-by-1½ in. glass vials with stoppers of gauze-covered cotton, kept in covered glass evaporating dishes with a piece of moist blotting paper on the bottom. Hourly temperatures were obtained from a thermograph in the insectary.

Certain phases of the life-history and behaviour were investigated in the laboratory, where the dishes containing the rearing vials were kept in an incubator at 21.1 ± 1° C. The relative humidity in the dishes was maintained at approximately 79 per cent by a vessel of saturated sodium carbonate solution,

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but the humidity within the vials was undoubtedly raised by the pieces of leaf bearing the mites supplied for food.

Although the chief prey of *S. punctillum* in peach orchards was the European red mite, *Metatetranychus ulmi* (Koch), this species could seldom be obtained in sufficient numbers on leaves free of toxic residues to supply the reared insects. They were therefore fed largely on the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, reared on broad bean, *Vicia faba* L., or scarlet runner bean, *Phaseolus coccineus* L. Fresh pieces of leaf bearing heavy infestations of the mite were placed in the vials daily. Mites reared on scarlet runner bean were transferred to peach or cherry leaves, because the hooked trichomes on the foliage of this bean tore the integument of the coccinellids; larvae were quickly killed by contact with the leaves, and the lives of adults were shortened by laceration of the delicate membranes of the terminal abdominal segments when these were everted and pressed to the leaf as an adhesive organ and during defecation. Johnson (1953) reported the injurious effect on aphids of the similar but more abundant trichomes on the foliage of the common bean, *Phaseolus vulgaris* L.

The adults were overwintered in ½-by-8-in. glass tubes loosely filled with 3 in. of broken dead leaves and inserted in a pot of sand set into the earthen floor of the insectary. The tubes were stoppered with plugs of cotton and dead leaves were piled around them.

Orchard Studies.—Populations were sampled each year in two or three Elberta peach orchards, divided into plots of approximately 100 trees each. Each plot in any one orchard received a different spray treatment, which was usually repeated for three or more years.

The populations of the immature stages of *S. punctillum* were sampled simultaneously with those of the European red mite and other flightless insects and mites by leaf collections made at intervals of about two weeks, from each tree except those in the outside rows. The number of leaves per tree varied at first but was later standardized at six. All plots in any one orchard, and usually in two orchards, were sampled on the same day. As they were picked from the trees the leaves were placed in covered tin cans, which were stored in a refrigerator at 4 to 6°C. At first the insects and mites on the leaves were counted during several days by direct observation under a binocular microscope; this method was accurate but very laborious. In 1952 and 1953 the leaves were brushed in a Henderson-McBurnie mite-counting machine, which concentrated the organisms on a glass disk; the counts were apparently equally accurate and required much less time.

The adults, which drop when disturbed, were sampled by holding a cloth-covered tray beneath a small branch while the latter was hit with a rubber-covered stick. Because jarring dislodged the larger fruits, after late June a broad brush made from a household broom was swept quickly over the branch, and the dislodged insects were collected from the tray by an aspirator, or a brush or finger-tip wet with alcohol. To reduce variations from changing weather conditions during the 2 or 3 hrs. required to sample an orchard, one row was sampled successively in each plot until all were sampled. Jarring and brushing were useful methods of determining the time of first appearance in the orchards and the relative abundance in the different plots in any one orchard, but the records obtained on different days or in different orchards were not strictly comparable because the catches were strongly influenced by weather

conditions. Sampling by these methods was satisfactory only when the trees were completely dry, the wind very light, and temperatures relatively low. At temperatures much above 21° C. many of the beetles took flight instead of dropping to the tray. Because of the exacting requirements, jarring or brushing could not be done on a regular schedule; on occasions the weather was unsuitable for two weeks or more.

Observations were frequently made in other peach orchards and occasionally in plum, cherry, and apple orchards.

To determine the extent of predation on winter eggs of the European red mite, all eggs on the terminal 3 in. of a year-old twig from each tree in a plot were counted under a binocular microscope in December.

Life-History

Hibernation.—Adults of *S. punctillum* may hibernate in deep litter in woodlands and under very sparse cover in the orchards. Attemps at collecting hibernating beetles by placing ground litter in light-tight boxes were unsatisfactory because large numbers of spiders filled the boxes and collecting tubes with webbing and preyed upon the beetles. However, 19 beetles were obtained from 1 bu. of fallen leaves collected in early April, 1948, from a wooded creek bank adjacent to a peach orchard heavily infested with the European red mite in 1947. In 1949 about 1 bu. of fallen leaves collected in the orchard yielded 3 beetles, and 0.5 bu. of leaves from a cherry orchard yielded 1 beetle. The leaves in both orchards were thinly distributed and seemed to offer very little protection. None were collected from a few other samples of ground litter or the upper 0.5 in. of soil from the orchards.

Experiments were carried out in 1949 and 1950 to determine the conditions affecting hibernation. Tin cans, 6 in. in diameter and 8 in. high, with the bottoms removed were set into the earthen floor at the side of the insectary, where conditions approximated those in the field although the cans were partly sheltered from rain and snow. One can was filled with earth topped with 2 in. of fallen leaves and debris from a woodland, one with earth alone, and another with a piece of orchard grass sod. Forty beetles collected in the orchards in late September and October were placed in each can on October 21, 1949, with a few bean leaves bearing two-spotted spider mites, and cloth tops placed over them. Forty adults were also placed in a can on an insectary shelf, containing a piece of decayed, loose-barked tree limb. In early April cone-shaped plastic tops with collecting vials at the apices were placed over the cans.

From the can containing dead leaves, 20 per cent of the original number of beetles emerged; from earth alone, 27.5 per cent; from sod, 27.5 per cent; and from the limb, none. High mortality was to be expected among field-collected adults of varying ages. The results confirmed field observations that the beetles may hibernate successfully in various types of ground cover or on nearly bare soil but that they cannot do so much above ground level. They were frequently found in the fall beneath bark scales on peach and apple trunks and also in corrugated paper bands placed around the trunks, but no living ones were found in these situations when the trees were examined in April. Low temperatures may destroy them on the trees but low humidity may be at least as important.

Developmental Stages.—The durations of the immature stages at a constant temperature of 21.1° C. and 79+ per cent relative humidity, as determined from observations at 12-hr. intervals, are given in Table I. The fourth larval period includes a prepupal period of about one day. The complete developmental

TABLE I
Duration in Days of the Developmental Stages of *S. punctillum* at 21.1° C. and 79 per cent Relative Humidity (45 individuals)

Stage	Range	Mean
Egg	5.5– 6.0	5.70 ± .04
Larva		
1st instar	2.0– 4.0	2.61 ± .05
2nd "	1.5– 2.5	1.81 ± .04
3rd "	1.5– 3.5	2.13 ± .05
4th "	3.0– 4.5	3.67 ± .05
Total	9.0–12.0	10.25 ± .08
Pupa	4.5– 6.0	5.20 ± .04
Total	20.0–23.0	21.12 ± .12

period for 16 males averaged 21.31 ± .18 days; for 29 females, 21.02 ± .15 days; the difference was not significant by Student's *t* test.

The durations of the stages reared in the insectary at temperatures closely approximating those in the orchards and examined once a day are given in Table II. The duration at any one mean temperature showed considerable variation, probably because of the effects of varying temperatures; this was particularly noticeable among those reared late in the season, when temperatures were below the developmental threshold for part of the time. From the last week of June to the end of the third week in August, when *S. punctillum* is breeding most rapidly, mean temperatures at Vineland Station fall within the range of 20 to 21.9° C., and during this period most individuals required 20 to 24 days to complete their development. Earlier in the season most matured in 25 to 29 days. In late summer and fall development was progressively prolonged. During the excessively hot summer of 1949, when the daily mean temperatures averaged 26° C. or higher for periods of two weeks or longer, development was greatly accelerated, a minimum of 14 days being required for completion.

Longevity and Fecundity of Females.—As the long lives of the females made their study very time-consuming and exposed them to the hazards of handling to an unusual extent, complete records were obtained for only a small number. Those on egg production were particularly unreliable because the females sometimes ate their own eggs. The extent of this predation apparently varied among individuals; hence the maximum figures for oviposition may represent a closer approximation to the true values than do the means.

Details of those females that oviposited and apparently completed their normal life-span are given in Table III. Of 10 females maturing from August 6 to September 12, 1950, none oviposted that season; 5 died during the following winter. The five survivors oviposited in 1951; 2 died in July (one probably injured) and 2 in the winter of 1951-1952. The one survivor oviposited in 1952 and died during hibernation in 1952-53. Of 11 females maturing from June 24 to July 11, 1951, all oviposted the same season; 1 died in the summer and 2 during the following winter. Of the 8 survivors, 1 died in June without ovipositing;

TABLE II
Durations in Days of the Developmental Stages of *S. punctillum* at various Temperatures in the Insectary

Mean temp., °C.	Egg			Larva			Pupa			Egg to adult		
	No.	Range	Mean	No.	Range	Mean	No.	Range	Mean	No.	Range	Mean
30–31.9	4	3	3.0									
28–29.9	17	3–4	3.7				6	2–3	2.8			
26–27.9	20	3–4	3.5	12	7–9	8.2	8	3–4	3.4	4	15–16	15.2
24–25.9	77	4–5	4.6	25	7–12	9.1	33	3–5	3.8	20	14–18	16.5
22–23.9	37	4–6	5.0	31	7–14	10.1	50	3–6	4.5	33	17–23	19.4
20–21.9	128	5–8	6.0	123	8–15	11.6	68	4–7	5.0	119	19–28	22.1
18–19.9	67	6–9	7.2	50	11–17	13.4	62	4–7	6.5	67	22–33	27.1
16–17.9	67	7–12	9.3	32	13–22	16.0	18	7–12	8.7	30	27–43	33.9
14–15.9	42	10–16	12.6	16	15–34	22.5	14	9–14	12.0	13	35–49	41.3
12–13.9	10	12–15	13.5	1	30	30	5	11–15	12.8	1	64	64.0
10–11.9							6	14–19	15.7			
8–9.9							1	24	24.0			

7 oviposited, 5 of them dying in late August and September and 2 during the winter.

Among females that oviposited in the same season as they matured, egg production that season tended to vary with the time of maturity. Seven females maturing from June 24 to July 1, 1951, laid an average of 576.9 eggs; 6 maturing from July 8 to 16, 391.3; and 8 maturing July 28 to August 8, 60.1. Four females (Table III) maturing from August 6 to September 12, 1950, but not ovipositing the same season, averaged 408.2 eggs in 1951. In their second season of oviposition, the 8 females in Table III averaged 478.6 eggs. The total egg production of the 14 females listed in the table averaged 748.1.

Seven females that matured from July 28 to August 8, 1951, and had laid 8 to 149 eggs during that season, were brought into the laboratory in January, 1952, and held at 21.1 ± 1° C. They lived from 46 to 156 days in the laboratory and laid from 625 to 1,403 eggs, with an average of 1,050.4. The total production, including those laid the previous summer, ranged from 642 to 1,509, with an average of 1,084.6. The higher recorded production of these females may have been partly due to examination at 12-hr. intervals for the first 56 days, thus allowing them less opportunity to destroy their eggs than in the case of the insectary-reared females that were examined at 24-hr. intervals. Although these records are not for normal conditions in the field, they indicate the reproductive potential of the species.

The eggs were laid singly at irregular intervals; as will be shown later, most were laid during daylight. The daily production varied greatly, both among different females and also during the course of a single individual's life; temperature had an obvious effect on the rate but much of the variation could not be explained. Occasionally a female would stop ovipositing for a day or rarely longer, to resume at an increasing rate. Usually the rate decreased as the beetles

TABLE III
Fecundity and Longevity of 14 Females of *S. punctillum* in the Insectary

Date of maturation	1951					1952					Total eggs	Longevity days
	First eggs	Last eggs	Oviposition period, days	No. eggs	Died	First eggs	Last eggs	Oviposition period, days	No. eggs	Died		
1950												
Aug. 6	May 28	Oct. 4	128	729	*						729	435+
15	May 29	Oct. 4	127	399	*						399	426+
29	May 29	July 10	42	197	July 12						197	317
Sept. 12	May 26	Aug. 9	75	308		May 19	Sept. 19	123	982	*	1,290	786+
1951												
June 24	June 30	Aug. 20	51	427		May 21	Aug. 22	92	665	Aug. 25	1,092	428
26	July 3	Aug. 23	51	541		May 12	Aug. 11	91	576	*	1,117	499+
26	July 10	Aug. 30	51	567				0	0	May 5	567	314
26	July 12	Sept. 7	47	469	*						469	111+
27	July 3	Sept. 17	76	549		May 16	June 20	45	184	Sept. 12	743	443
July 1	July 13	Oct. 21	91	845	*						845	106+
5	July 15	Sept. 12	59	518		May 12	Aug. 15	95	592	Sept. 2	1,110	425
7	July 16	Aug. 25	40	155		May 19	July 4	46	124	Sept. 27	279	448
8	July 14	Oct. 6	74	634		May 10	July 4	55	193	Aug. 29	827	418
11	July 17	Aug. 18	32	297		May 12	July 19	68	513	*	810	484+

*During hibernation.

neared the end of the oviposition period, before either death or diapause. The greatest number of eggs laid by a female in a 24-hr. period was 28 but the average daily rate was much lower. In July, 1951, 17 females in the insectary averaged 8.5 eggs per day with a range of 2.5 to 13.2. The 7 females held at 21.1° C. in the laboratory and examined at 12-hr. intervals oviposited at a very high and uniform rate, averaging 11.7 eggs per day, with a range of 9.5 to 15.6.

Long before the end of the season most females entered diapause; oviposition stopped although feeding and other activity continued. The ovaries retrogressed and the fat body enlarged greatly. Among 39 females that eventually entered hibernation in 1950, 1951, and 1952, 2 entered diapause in July, 21 in August, 11 in September, and 5 in October. The latest date for oviposition was October 21, 1951. Although the records were few the time when the females entered diapause averaged approximately the same for all ages; consequently late-maturing ones often laid very few eggs during their first season.

In 1949, 1950, and 1951, all insectary-reared females maturing before late July oviposited the same season; those maturing after early August did not, irrespective of the generation to which they belonged. In the three years mentioned the maturation dates of the last ovipositing and the first non-ovipositing females respectively were July 25 and August 4, August 4 and 1, and August 8 and 15. Females emerging from pupae collected in the orchards behaved similarly, although they were too few to determine whether the beginning of diapause coincided with that in reared females. Only the earlier-maturing individuals of the first and second generations oviposited the same season; the majority of these broods and all of the third matured too late.

Longevity of Males.—Although complete records were obtained on very few males, their longevity appeared to be less than that of females. Of 20 males maturing from July 14 to September 12, 1950, 11 died during the following winter; 1 died in May, 1 in June, and 1 in August, 1951; 6 entered hibernation in the fall of 1951 but none survived the winter. The greatest length of life was 449+ days. These males were confined with females only at infrequent intervals totalling not more than 15 days; whether more prolonged contact would affect their longevity is not known.

Some males in their second summer showed impaired fertility; although they copulated with females the latter sometimes laid fertile eggs for short periods only, or occasionally not at all.

Whether males enter a diapause similar to that of the females was not determined; if they do they enter it much later in the season, for males maturing in late August and early September copulated readily with receptive females.

Relations of Sexes.—Among 193 reared individuals the ratio of males to females was 50.5: 49.5, indicating a normal sex ratio.

The length of time a pair remained in copula varied greatly, from a few seconds to 30 min. The shorter periods were apparently not successful. Females in diapause did not accept copulation and had little attraction for the males, although the latter sometimes attempted union with any female or with one another. Ovopositing females copulated repeatedly, often on successive days. A single mating was not sufficient to maintain production of fertile eggs during the seasonal oviposition period of most females; the precise duration of fertility was not determined but in one female in the insectary it was at least 50 and not more than 65 days, and in 6 others it ranged from 32 to 51 days. In the laboratory at 21.1° C. a female produced fertile eggs for at least 62 and not more

than 69 days; 873 eggs were laid within the minimum period. As previously mentioned, females were sometimes fertile for only short periods after matings with older males

A female that emerged from hibernation in May, 1952, laid fertile eggs for at least 58 days although it had not been in contact with a male since August 27, 1951. Six other females with a similar history laid only infertile eggs in the spring until they were newly mated.

The length of the preoviposition period was influenced by the time when the female was fertilized. Among 9 females fertilized 1 to 4 days after reaching maturity the preoviposition period ranged from 3 to 5 days, with an average of 3.8; among 13 females fertilized 5 or more days after maturity the range was 5 to 18 days and the average 8.6. The difference was highly significant by Student's *t* test. Unfertilized females eventually produced eggs unless they matured too late in the season. The rate of oviposition often, but not always, slowed when a previously fertile female began to lay infertile eggs.

Seasonal History.—The adults of both sexes hibernate. Attempts to determine the period of emergence in the spring by placing cages over natural hibernation sites were not successful; in large cages the beetles could not be detected because of their minute size, and in darkened cages designed to concentrate the beetles in glass vials the latter quickly became filled with spider webbing. The only records obtained were from the hibernation tubes previously described, in which adults had been placed in the fall. In 1948, 19 emerged from May 15 to June 14; in 1949, 3 from April 21 to May 5; in 1950, 60 from May 12 to June 7; in 1951, 23 from May 2 to 21; in 1952, 13 from April 22 to 25. The two sexes appeared at approximately the same time. As such conditions as depth of cover, moisture, and insolation vary widely in natural sites, spring emergence in the field probably extended over a longer period than in the tubes.

In the 5 years from 1948 to 1952 adults were first jarred from the trees in the study orchards on May 19, 3, 15, 22, and 23 respectively, and they may have been present for a few days before these dates because jarring was usually done at weekly intervals. A lag of a few days to at least two weeks thus occurred between the first emergence and the first occurrence on the trees. This lag was especially marked in 1952, when a very warm spell during the third week of April stimulated emergence but was followed by a long period of abnormally cold weather that prevented flight.

The beetles appeared on the trees several days after the eggs of the European red mite had begun to hatch except in 1950, when a few beetles were present at least 2 days before hatching began.

In the insectary the first eggs in 1949 to 1952 were laid on May 12, 29, 21, and 10 respectively, and they were present in the orchards at the first examination after these dates.

The dates when the first adults of each generation matured in 1949 to 1951 respectively were: first generation, June 18, 26, and 22; second, July 13, 24, and 20; third, August 5, 22, and 16. As some females of the overwintered and first two summer generations oviposited throughout the summer, adults of all three summer generations continued to mature until checked by cold weather; the last adults matured on October 21, 17, and 24 in 1949, 1950, and 1951 respectively. However, an increasing proportion of the females entered diapause as the season advanced and oviposition of the others declined with colder weather, so that relatively few adults matured after the middle of September.

Some females continued to oviposit very late, until October 21 in 1951, but all immature forms were killed by the first severe frost.

In the orchards, very few larvae were found after late September even where late infestations of the European red mite were present. Adults were often common in early October but gradually disappeared during the month as leaf-fall progressed. The time when the adults entered their hibernation sites was not determined but presumably coincided with their disappearance from the trees.

The remarkably long life of the adults, coupled with the relatively short developmental period, allows the coexistence of the parent female with several generations of offspring. A late-maturing female that oviposited during the following two seasons and her F_1 to F_6 generations of progeny might all be present late in the third season, and some individuals of all except the F_6 generation might be ovipositing.

Food Habits

Species Attacked.—*S. punctillum,* like other species of the genus, is a highly specialized predator of tetranychid mites. Kapur (1948) reviewed the literature on the hosts of various species and listed *Tetranychus telarius* (L.), *T. turkestani* Ugar. & Nik., and *Metatetranychus ulmi* (Koch) (=*Paratetranychus pilosus* (C. & F.)) among the prey of *S. punctillum.* Collyer (1953) gave a further reference to its attacks on spider mites in various European countries.

In the Niagara Peninsula *S. punctillum* was found attacking the European red mite on peach, apple, plum, and cherry; the two-spotted spider mite on peach, apple, and various herbaceous plants; *Paratetranychus ununguis* (Jac.), on Chinese chestnut, *Castanea mollissima* Blume; and *Paratetranychus* sp. on arbor-vitae, *Thuja occidentalis* L., and bur oak, *Quercus macrocarpa* Michx. It was not seen to eat the clover mite, *Bryobia praetiosa* Koch, in the orchards, and was absent from the few heavy infestations of this mite observed on plum and apple. Only an occasional mite was consumed when numbers of *B. praetiosa* were confined for two days with adults or larvae of *S. punctillum.*

Both larvae and adults attacked all forms of the mites. First-instar larvae fed largely on the eggs and smaller nymphs, but even newly hatched larvae seized and eventually overpowered adult mites after being pulled along for a short distance.

S. punctillum also attacked predacious mites. When adults were placed on bean leaves bearing the two-spotted spider mite and the predator *Typhlodromus fallacis* (Garm.), they ate the eggs of the latter as freely as those of the spider mite whenever they encountered them. The adults were also observed to eat the eggs of a mixed population of *Typhlodromus* spp., largely *tiliae* Oudms., associated with the European red mite on plum. They also attempted to seize the active forms of *Typhlodromus* spp.; they captured some small nymphs but the adults were too agile. Whether *S. punctillum* larvae also attack *Typhlodromus* spp. was not determined.

Starving adults and larvae fed on aphids to a very limited extent, avoiding them on most contacts. Fourteen larvae of various instars were placed in vials with chrysanthemum leaves infested with *Rhopalosiphum rufomaculatum* (Wils.). Three third-instar larvae moulted into the fourth instar and one eventually became adult, but the rest did not moult and died within 7 days. Several were observed feeding on the aphids and apparently on the honey dew; the latter impeded the larvae and frequently trapped them. The feeding of adults on aphids is discussed later.

Method of Feeding.—The larvae feed by sucking the contents of the mites or eggs; the exoskeleton is not consumed. Extra-oral digestion, in which the gut contents of the larva, perhaps accompanied by salivary secretion, are alternately regurgitated and sucked out of the prey until its body contents are liquefied, occurs as described by Collyer (1953) in *S. punctillum*, by Fleschner (1950) in *S. picipes* Csy., and by Robinson (1953) in *S. punctum.* The adults masticate their prey and usually ingest it, but parts of the exoskeleton of larger mites are sometimes discarded. They also eat the eggs of the two-spotted spider mite and usually the summer eggs of the European red mite completely, but basal portions of winter eggs of the latter are frequently left on the swigs.

Rate of Feeding.—Very few feeding trials were conducted with the European red mite because it was rarely found in sufficient concentration on unsprayed foliage. In late May of 1949 some peach leaves were found that bore heavy infestations of the protonymphal to imaginal stages of the first generation; these were fed to ovipositing females of *S. punctillum.* Both males and ovipositing females were fed on two-spotted spider mites freshly transferred from bean to peach leaves; the mites were mostly adults and deutonymphs, but the former continued to oviposit while confined with the beetles so that varying numbers of eggs were also present.

The numbers of mites consumed per day are given in Table IV. Ovipositing females ate a daily average of 42.8 European red mites or 40.0 two-spotted spider mites, as well as small numbers of the eggs of the latter. Diapause females ate considerably fewer mites but the numbers were not counted. Males consumed an average of 19.9 two-spotted mites per day. Both sexes tended to eat more mites at higher temperatures but this effect was not consistent among the small number of beetles tested. Collyer (1953) found that adults of unstated sex and condition consumed an average of 20 adult females of the European red mite per day.

Consumption of two-spotted spider mites by the larvae of *S. punctillum* was determined by confining the larvae with pieces of peach leaf bearing freshly transferred mites as described for the adults, and counting the numbers of empty exoskeletons after 24 hr. Two male larvae ate 184 and 274 mites respectively and some eggs during their developmental period; 5 female larvae ate 206 to 277 mites and some eggs. The average for the 7 larvae of both sexes was 238.6 mites, over half of the total being consumed during the fourth instar. Fleschner (1950) found that 5 larvae of *S. picipes* ate 247 to 486 of the citrus red mite, *Paratetranychus citri* (McG.), when a surplus of prey was present, but when the supply was restricted, 4 larvae reached maturity on 135 to 181 mites. The minimum number of prey required to bring *S. punctillum* to maturity was not determined. When larvae were fed only on alternate days none reached maturity except those already in the fourth instar.

Alternative Foods.—The erratic occurrence of tetranychid mites under natural conditions suggested that adults of *S. punctillum* must be able to survive for long periods on alternative foods. An experiment was set up to test this hypothesis, with such possible foods as were available in the laboratory and greenhouse in the early spring.

Adults that had fed on two-spotted spider mites for 5 days after maturity were confined individually in vials with no food or water; water supplied in smaller vials filled with absorbent cotton; broad bean leaves; pieces of raisin; young peach leaves with secreting foliar glands; or pieces of chrysanthemum

TABLE IV
Numbers of Mites Consumed per Day by Adults of *S. punctillum* at various Mean Temperatures

No. of beetles	Mean Temp. °C.	Mites consumed	
		Range	Mean
FEMALES FED EUROPEAN RED MITES			
5	18.6	25–50	40.7
5	24.9	37–59	50.3
5	14.5	32–64	48.8
3	10.2	21–31	23.2
Average			42.8
FEMALES FED TWO-SPOTTED SPIDER MITES			
3	21.4	52–87	66.3
4	17.2	38–66	52.0
4	16.4	22–45	34.2
4	17.4	24–44	32.5
4	18.6	13–35	21.8
Average			40.0
MALES FED TWO-SPOTTED SPIDER MITES			
2	21.4	32–35	33.5
4	16.4	8–19	15.2
4	17.4	18–28	22.5
3	18.6	3–24	13.7
Average			19.9

leaf bearing the aphid *Rhopalosiphum rufomaculatum* (Wils.) and its honey dew. A series fed on mites was not included because it had been found that normal life expectancy on this food was much longer than the 105 days' duration of the experiment. The vials were held at 21.1 ± 1° C. and 79 per cent relative humidity.

The beetles were seen feeding frequently on the deliquescing surface of the raisins and on the secretion of the peach foliar glands, and occasionally on the aphids. They also appeared to feed on the honey dew. One was observed chewing the cut edge of a bean leaf.

Six beetles kept without food or water lived 4 to 5 days with an average of 4.5; 6 with water, 3 to 7 days with an average of 4.7; 8 with bean leaves, 5 to 7 days with an average of 5.8; 8 with raisins, 9 to 74 days with an average of 41.5; 6 with peach foliar glands, 6 to 105+ days (one living at the end of the experiment) with an average of 43.2+; and 8 with aphids, 6 to 105+ days (5 living at the end of the experiment) with an average of 69.9+. There was no consistent difference in longevity between the sexes, which were determined by dissection at death or the end of the experiment. Several other newly matured or ovipositing adults that were starved lived about as long as those in the experiment.

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Those in diapause that had fed on mites for some time and accumulated fat survived much longer, commonly for 2 weeks and, late in the season under falling temperatures, up to 46 days.

None of the females in the foregoing experiment produced eggs, although a few of the same origin did so when fed mites for a short time. Another experiment was set up to give further information on the effect of food on oviposition. Seven ovipositing, wild-caught females kept at 21.1° C. were fed in turn for a number of days on each of the two-spotted spider mite, the aphid *Rhopalosiphum rufomaculatum*, the mite, peach leaves with secreting glands, and the mite. The total number of eggs laid on successive days were: (mites) 55, 62; (aphids) 7, 1, 0, 0, 2 (small and abnormally shaped), 0, 0; (mites) 7, 33, 62, 81, 78, 102, 96; (secretion) 0, 0, 0; (mites) 8, 21, 40, 57.

Although the apparently abrupt decline or cessation of oviposition when the beetles were transferred from mites to aphids or secretion might have been partly due to their destroying their own eggs, the initially low rate of production when they were again fed on mites proved that the other foods had greatly reduced or prevented egg production.

Although the adults fed on aphids in the laboratory they were not seen doing so in the orchards, and they were not found in the many aphid colonies examined in peach orchards or elsewhere. Presumably adults of *S. punctillum*, in the absence of mites, may eat aphids casually encountered, but are not attracted by them and do not remain in their vicinity. The green peach aphid, *Myzus persicae* (Sulz.), was the only aphid, apart from straggling migrants, found on peach trees, and it was absent from approximately the end of June until late September.

Adults of *S. punctillum* were seen feeding on the secretion of peach leaf glands, really extrafloral nectaries, a number of times in the orchards. This secretion, also produced by other species of *Prunus*, is sweet and very attractive to ants and honey bees. According to Knapheisowna (1927) it contains sugars and tannins. It is produced most abundantly by young, expanding leaves; when the latter reach maturity the glands gradually become functionless. In mature orchards most secretion stops during August, the time varying with weather and cultural conditions.

As they fed on raisins, starving beetles may also obtain some nutriment in the orchards from ripening fruit in which the epidermis is broken by insect or other injury, although they were not actually seen doing so.

According to various authors cited by Balduf (1935), and to unpublished work of the present writer, a number of the common aphidiphagous coccinellids feed to some extent on pollen and fungus spores; possibly *S. punctillum* also feeds on such materials when mites are not available.

Behaviour of Adults

General Behaviour.—As encountered in the field, the adults usually moved slowly and erratically over the foliage and twigs, or rested, usually on the under sides of the leaves. They were rarely seen except on mite-infested trees. They flew readily on warm days and, to judge from their dispersion, for considerable distances. They exhibited the common coccinellid habit of 'death-feigning' when disturbed. However, in the laboratory they soon became conditioned and, after one or two disturbances that produced 'death-feigning', further stimulation within a short time caused running or flight. Also, if the first of a rapid series of increasing stimuli such as jarring or probing was too weak to cause 'death-feigning', this reaction was not produced when the stimulus reached a

TABLE V
Total Number of Eggs Deposited During 12-hr. Periods by Females of *S. punctillum* under Different Light Regimes
(7 Females in Regimes 1–4, 6 Females in Regime 5)

Light regime	No. 24–hr. periods	Day (8:30 a.m.—8:30 p.m.)		Night (8:30 p.m.—8:30 a.m.)	
		No.	Per cent	No.	Per cent
1. Bright days, dark nights	6	330	63.2	192	36.8
2. Dark days, bright nights	7*	295	36.2	521	63.8
3. Continuous darkness	6	297	40.8	431	59.2
4. Continuous light	8	421	46.4	485	53.6
5. Bright days, dark nights	7	318	62.6	190	37.4

*One day of adjustment omitted.

level that would normally induce it. This behaviour has an important bearing on population sampling in orchards, because the beetles on trees disturbed by wind would less likely be collected by jarring.

Rough handling induced 'reflex bleeding', an exudation of a whitish liquid from the femoro-tibial articulation, probably a glandular secretion as shown by McIndoo (1931) in *Epilachna varivestis* Muls.

The adults were usually photopositive and general observations suggested that they were largely diurnal. In other studies a group of females was examined and the eggs removed at 8:30 a.m. and 8:30 p.m., affording an opportunity to investigate the effect of light on feeding and oviposition. A 25-watt incandescent bulb hung outside a window in the incubator, held at 21.1 ± 1° C., provided light for the rearing vials about 12 in. distant; when darkness was desired the glass vessel containing the vials was enclosed in a cardboard box. The same lot of ovipositing females, at first 7 and later 6, was exposed successively to different light regimes, each of about a week's duration.

Under a regime of dark nights and bright days, nearly twice as many eggs were laid during the day as at night (Table V), though individual females occasionally deviated from this rhythm. Next, under bright nights and dark days, after one day of adjustment the proportions of eggs were almost exactly reversed and the greater number was laid at night. Next, in continuous darkness the rhythm of the previous regime was maintained, the greater number of eggs being laid at night, but the difference was somewhat less. Next, under continuous light, the same rhythm was maintained for the first 4 days, after which the rate of oviposition was practically uniform. Lastly, under the original regime of dark nights and bright days, the original rhythm of high diurnal and low nocturnal oviposition immediately reappeared. Analysis of variance showed that the difference between day and night oviposition were highly significant for all regimes except that of continuous light.

Through the greater part of the experiment the average number of eggs per female per 24 hr. remained approximately the same; somewhat lower production during the first and last regimes was probably the effect of age of the beetles, as they may not have reached maximum production at the beginning

of the experiment and were obviously past it at the end. The numbers of mites consumed were not determined, but there were obvious differences that paralleled those of egg production.

In the laboratory the adults usually were stimulated by light and became quiescent as it was reduced. During the daytime, periods of activity of 1 to 20 min. or more alternated with greatly varying periods of rest up to 2 hr. or more. If food was scarce, activity was more prolonged. Presumably in darkness the inactive periods are prolonged and broken only by the need for food or the pressure of accumulating eggs. Under natural conditions a much greater proportion of adult activity must occur during daylight, owing to its greater length in northern latitudes and to the depressing effect of lower temperature at night.

Park (1940), in his review of nocturnalism, distinguishes species that have exogenous activity rhythms directly controlled by the environment, and that do not show periodicity under constant lighting condition, from those having endogenous periodicity, which persists under constant conditions but may be modified to a certain extent by the environment. *S. punctillum* lacks any truly endogenous periodicity; its activity is readily modified by external conditions but a particular rhythm induced by a certain light regime may persist for several days after the insects are transferred to constant conditions.

Oviposition.—The eggs are laid singly wherever the female happens to be when they are ready for deposition. As eggs are produced only by females that feed on mites, and as the females remain for an appreciable period only on mite-infested foliage, they are usually laid in or near mite colonies. On foliage infested with the European red mite and the two-spotted mite, which are found chiefly on the lower surfaces, eggs of *S. punctillum* were also deposited there. On chestnut leaves, *Paratetranychus ununguis* was confined to the upper surface and the eggs were laid there.

Detection of Prey.—An adult that has not recently fed usually runs rapidly and often in one direction for some distance. If it encounters a mite it stops and eats it, and then proceeds much more slowly with frequent turns as it searches the area in the immediate vicinity. If more prey is not found it may again resume a rapid and direct course. Similar behaviour has been noted in various parasites and predators by other workers, e.g., by Fleschner (1950) in the larvae of *S. picipes*.

Although close observation of adults of *S. punctillum* in the field and laboratory suggested that they detected prey only by contact, some experiments were performed to learn whether odour was involved. A circular arena 8 cm. in diameter by 4 cm. high was constructed of fine plastic screening. Pieces of broad bean leaves heavily infested with the two-spotted spider mite were placed in two 2-by-2-cm. glass vials with the mouths covered with fine silk. Two similar vials contained uninfested leaves. A vial was inverted on each quadrant of the top of the arena, vials with and without mites being placed in alternate positions. The arena was placed in a glass moist chamber with saturated salt solution to maintain a relative humidity of 77 per cent at the room temperature of 22° C. Seven males of *S. punctillum* starved for 24 hr. were placed in the arena, the whole apparatus was put in a deep container to exclude lateral light, and a 60-watt incandescent bulb was placed 1 m. above the centre.

The beetles were very active and traversed all surfaces of the arena. Their positions were noted at frequent intervals for 1½ hr.; they did not show any preference for the vicinity of the vials, either with or without mites. The

cover of the chamber was then removed to allow air circulation and to maintain a steeper gradient of odour. The results were the same as in the first trial. Evidently the beetles could not detect the presence of mites through less than 1 mm. of silk and screen.

To determine whether the beetles were attracted to trails, including the silk strands, left by two-spotted spider mites, the latter were allowed to walk along a strip 3 mm. wide across a piece of lens paper by confining them between 2 glass slides. After 2 hr. the mites were quickly blown off the paper and the latter was inverted over a shallow stentor dish containing 2 adults of *S. punctillum* that had been starved for 5 hr. Illumination and temperature were the same as in the previous experiment. Within 15 minutes the beetles crossed the mite trails 53 times but gave no reaction that would show they detected them.

Behaviour of Larvae

Fleschner (1950) made an exhaustive study of the behaviour of the larvae of *S. picipes* in relation to prey-finding. As far as could be determined from general observations in the orchards and the laboratory, the behaviour of the larvae of *punctillum* was very similar. They were generally photopositive. Usually they appeared rather sluggish but starved larvae travelled rapidly for long periods. When such larvae were placed on peach foliage they traversed all surfaces and moved freely from leaf to leaf along the twigs, but showed a geonegative tendency by gradually ascending the twigs.

Prey was apparently detected only by contact. The larvae readily penetrated beneath the webbing spun by the two-spotted spider mite, loosening it by forward and upward thrusts of the head and supporting it by the tips of the pectinate setae on the dorsum.

When about to pupate the larva attached itself by the everted anal region near where it had completed feeding, usually on the lower surface of the leaf but occasionally on the upper surface of vertically hanging ones.

Population-Limiting Factors

Pesticides.—A fuller discussion of the effects of pesticides on the various predators of tetranychid mites in peach orchards will be published later, but the high toxicities of DDT and parathion to *S. punctillum*, resulting in practical elimination from sprayed orchards, must be mentioned because they have a very important bearing on population studies. Until 1948, DDT was not generally used in peach orchards, and plots experimentally sprayed with it were repopulated the following spring from surrounding areas. It was first used extensively late in 1948, and since 1949 practically all peach orchards in the Niagara Peninsula and most other vegetation in their vicinities have been sprayed annually with DDT or, more recently, parathion, and concomitantly the general abundance of *S. punctillum* has greatly decreased, even in unsprayed plots. Records of what may be considered normal abundance of *S. punctillum* in the experimental peach orchards are therefore available only for 1947 to 1949, but observations were made later on plum and other trees in areas where the species was still abundant.

Diseases, Predators, and Parasites.—A disease, presumably bacterial or virose, that caused liquefaction of the body contents occasionally attacked the larvae. In one peach orchard in 1948, 20.5 per cent of the larvae had been killed by disease on July 19 and 13.6 per cent on August 2, when the populations were at the unusually high levels of 39.9 and 19.9 per 100 leaves respectively. These values suggest that disease may be an important limiting factor at high population

densities. Usually the incidence was much lower and in a number of seasons diseased larvae were not noticed.

Larvae of *Chrysopa rufilabris* Burm. and *C. plorabunda* Fitch destroyed the eggs and larvae of *S. punctillum* at every encounter unless they had previously fed to repletion. In the few contacts observed they did not succeed in capturing the adults. Chrysopid larvae were the most important predators of *S. punctillum* in the study orchards, because of their relative abundance, activity, and high food requirements, but their numbers were only occasionally great enough to have any appreciable effect.

When eggs of *S. punctillum* were confined with *Typhlodromus fallacis* from a laboratory culture, the predacious mites soon died and the eggs hatched normally. A similar experiment was performed with a mixed population of several species of *Typhlodromus*, predominantly *tiliae*, collected from plum. In this case a mite was seen with its chelicerae inserted in an egg of *S. punctillum* and none hatched. Where they were not suppressed by pesticides, these mites were the commonest predators associated with *S. punctillum* but as they and *S. punctillum* are predatory on each other's eggs it was difficult to determine the ultimate effect on the populations of the latter.

Other polyphagous predators such as spiders, various Hemiptera, and thrips that probably prey upon *Stethorus* were seldom sufficiently numerous to have much effect.

No parasites were obtained from the many larvae and adults collected in the orchards and held for long periods.

Cannibalism.—With this species cannibalism does not appear to be a habit of appreciable significance. Actually, among several hundred contacts observed between females and their eggs, it was seen in only two cases, involving females which laid and ate infertile eggs. However, further evidence of cannibalism was afforded by the smaller numbers of eggs found in vials containing females after a 2-day period as compared with the numbers when the eggs were removed daily, which was the usual practice. For 45 sets of records, the average number of eggs for a 2-day period when they were removed daily was 17.8; for the next 2 days when they were removed only at the end of the second day, 13.8; and for the next 2-day period when they were again removed daily, 17.5. Analysis of variance showed that the numbers in the middle period were significantly less than in the first and last periods, presumably because more had been eaten.

The larvae ate the eggs only after being starved for several hours. In the presence of mites larvae did not destroy other larvae of the same size, as many as 10 being reared to maturity in a ½-by-3-in. vial, but after prolonged starvation some cannibalism occurred, especially by larger larvae upon smaller ones.

It may be concluded that cannibalism is not an important factor in limiting the increase of *S. punctillum* as it becomes extensive only when normal prey is lacking. The survival value of cannibalism has been pointed out by various writers, including Nicholson (1933).

Innate Factors.—As previously mentioned, from July onward an increasing proportion of the females cease ovipositing and enter diapause. The withdrawal of these individuals from the reproducing population reduces the potential increase considerably, and probably explains why *S. punctillum* is seldom abundant in late-season infestation of mites.

Although it limits the practical value of *S. punctillum* this behaviour is beneficial to the species under natural conditions. As mite populations dense

enough to support the reproduction of *S. punctillum* are unusual in undisturbed habitats, especially during the latter part of the season, the lesser food requirement of these individuals in diapause allows them to survive and enter hibernation in good condition.

Weather Conditions.—During the 3-year period of study, temperatures at some time during the day from June 1 to September 1 were always high enough to permit feeding and oviposition. Earlier and later in the seasons the numbers of individuals under observation were too few and oviposition usually too erratic to determine in the insectary the threshold for oviposition, but it was not below 12.5° C. Eggs were laid when the maximum temperature during the day was 14.4° C.

Cagle (1946), in his study of the European red mite at Blacksburg, Va., found that when the logarithms of the days required for completion of the incubation period and for subsequent developmental stages were plotted against mean temperature they conformed to straight lines. Cagle's graph for the immature stages (hatching to maturity) of the mite is given in Fig. 1, together with the duration of the larval period of *S. punctillum* plotted in the same manner. The points for the latter species fall on a curve, which becomes flatter and diverges increasingly from the line representing mite development as temperature increases. Curves for the egg and pupal stages of *S. punctillum* (not shown) were similar to that for the larvae but the curvature was less pronounced. Though the rates of development were recorded at two widely separated localities, the divergence of the curves is so marked that it probably represents a true difference between the species. This difference shows that higher temperatures accelerate the development of the mite more than that of *S. punctillum*, so that the efficiency of the predator decreases as the temperature increases.

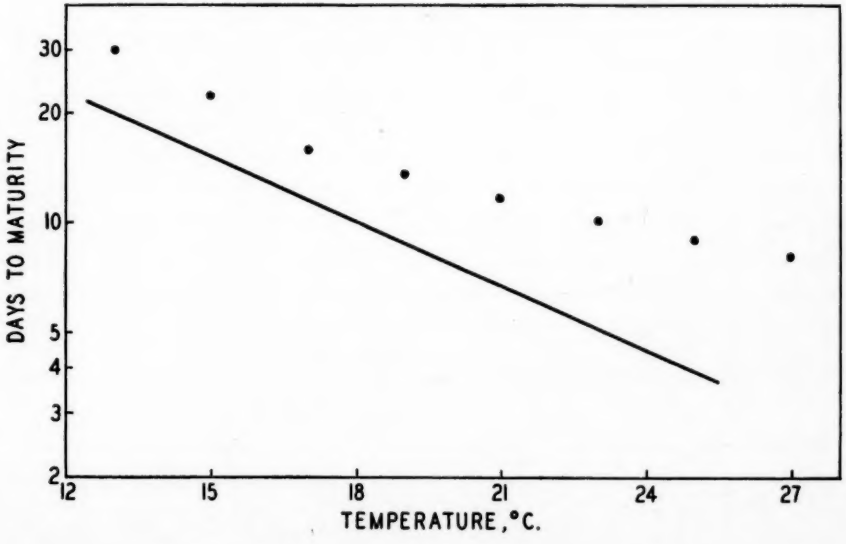

Fig. 1. Relation of time of development to mean temperature in the immature stage (hatching to maturity) of the European red mite (straight line, from Cagle, 1946) and in the larva of *S. punctillum* (points).

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The relatively small numbers of adults found in the spring as compared with the fall indicated a high winter mortality, undoubtedly influenced by temperature and amount of snow cover.

Food Supply.—In common with other predators that require a large number of prey to complete development, *S. punctillum* can survive and increase only where mites have reached a certain minimum density. To initiate a population of *S. punctillum*, the mite population must be sufficient to sustain the adults. The females do not produce eggs unless they can feed on mites, and they disperse from habitats where mites are scarce and congregate where they are abundant, apparently through random wandering. The density of the European red mite on peach, and probably other trees, in the spring follows a characteristic pattern that influences the behaviour of *S. punctillum*. The mites hatch in May shortly after growth begins and settle on the earliest expanded leaves, where they usually remain until mature, so that these leaves may bear large numbers of mites in late May and early June. As the adults mature they disperse over the rapidly expanding foliage, and the population per leaf drops abruptly. As the increase of leaf area on vigorous trees is often greater than the increase of the mite for another week or more, the population of the latter may not reach its original density until July, as shown in Table VI.

Adults of *S. punctillum* appear on the trees as the mites are hatching; they have frequently been seen feeding on the concentrations of young mites on the older leaves, and eggs are soon produced. However, unless the mites are very abundant the numbers of adults and eggs commonly decrease for a month or

TABLE VI
Numbers of the European Red Mite and of *S. punctillum* in Plot D, Peach Orchard H, 1949*

Organism	No. per 100 leaves							
	June		July		Aug.			Sept.
	7	20	4	19	1	11	30	12
Mites	83	20	64	313	3,280	7,050	67	15
S. punctillum								
eggs	2.2	1.1	0.3	0	0.94	4.8	0.2	0
larvae	0.5	0.9	0.47	0.2	1.4	5.3	0	0.2
pupae	0	0.3	0	0	0.3	1.4	0.7	0.5

Organism	No. per plot						
	Jarring	Brushing					
	June	July		Aug.		Oct.	
	1	13	27	11	25	1	
S. punctillum							
adults	69	4	0	104	63	13	
larvae	0	2	18	79	2	0	

*Spray schedule: May 23 and August, wettable sulphur, 8 lb. per 100 gal.

more, as shown in Table VII, plots B and C, and especially in Table VI. In these examples a shuck-fall spray of sulphur may have affected *S. punctillum* to a certain extent, but as it was applied at the beginning of rapid growth the effect would not be persistent. Adults were often found in numbers in the orchards soon after a sulphur spray. This early decrease of *S. punctillum* is partly an artifact due to increasing foliage area, but to a large extent it is real and caused by lack of food for the adults.

The further increase in numbers of *S. punctillum* is dependent upon the presence of sufficient prey to bring the larvae to maturity. Fleschner (1950), on theoretical grounds, calculated that a last-instar larva of *S. picipes* required one adult female of the citrus red mite per 46.7 sq. in., evenly distributed over a uniform surface; experimentally he found that one per 43.2 sq. in. was required. These two species are very similar to *S. punctillum* and the European red mite respectively. A conservative estimate of the average area of a peach leaf, based on some measured samples, was 11 sq. in.; Fleschner's figure of one mite per 43.2 sq. in. as the minimum survival density is therefore equivalent to 25.5 mites per 100 leaves. However, even if it is assumed that the searching abilities of the two *Stethorus* species are similar, it would be hazardous to apply results obtained on a uniform surface to the complex topography of a tree. A peach leaf, which is glabrous, might be considered essentially uniform, but the pubescence of the lower surfaces of apple leaves greatly slowed the progress of the larvae. Also, low host density would begin to restrict increase in numbers of *S. punctillum* at a point considerably above the starvation level, because the

TABLE VII
Numbers of the European Red Mite and of *S. punctillum* per 100 Leaves in Peach Orchard S, 1947 and 1948*

Plot	Organism	1947					
		June 23	July 10	July 23	Aug. 6	Aug. 18	Sept. 2
A	Mites	12	116	3,860	8,360	9,704	439
	S. punctillum						
	eggs	–	–	28.5	26.4	0	0
	larvae	0	4.4	6.3	22.7	0.5	0
	pupae	0	0	0.9	5.3	0	0
B	Mites	0	4	474	1,917	13,141	160
	S. punctillum						
	eggs	–	–	1.9	23.9	0.5	0
	larvae	0	0.5	0.3	8.3	0	0
	pupae	0	0	0	0	0	0
C	Mites	1	18	1,550	5,158	9,964	222
	S. punctillum						
	eggs	–	–	7.1	24.7	33.5	0
	larvae	0	0.5	0.6	7.9	6.3	0
	pupae	0	0	0	0	0	0

Plot	Organism	1948							
		June	July			Aug.		Sept.	
		21	7	19	2	16	30	13	27
A	Mites	333	1,170	4,540	11,510	12,275	900	152	1,855
	S. punctillum								
	eggs	8.3	14.5	64.8	19.6	1.4	0	0	0
	larvae	1.6	12.9	33.9	18.9	0.2	0	0	0
	pupae	0	0.2	1.6	4.1	2.4	0	0	0
B	Mites	41	212	968	4,625	2,622	1,020	514	4,440
	S. punctillum eggs	2.8	1.2	11.4	19.6	0.93	0.2	0	0
	larvae	0.4	1.1	1.7	12.2	0	0	0.2	0
	pupae	0	0.2	0	0.7	0	0	0	0
C	Mites	6	27	58	82	339	408	290	2,745
	S. punctillum eggs	0	0.2	0.2	0	0	0	0	0
	larvae	0	0	0	0	0	0	0	0
	pupae	0	0	0	0	0	0	0	0

*Spray schedules as follows:—

Amounts per 100 gal.: sulphur, wettable, 8 lb. (June), 10 lb. (August); DDT, 50%, 2 lb.; acaricide, 40% di-(*p*-chlorophenoxy) methane, 2 lb. (1947), 2½ lb. (1948).

1947

A, June 5, sulphur; Aug. 7, DDT; Aug. 27, DDT and sulphur.
B, June 5, sulphur; Aug. 7, DDT; Aug. 27, DDT, acaricide, and sulphur.
C, June 5 and Aug. 27, sulphur.

1948

A, June 3, sulphur; Aug. 5, DDT; Aug. 24, DDT and sulphur.
B, June 3, sulphur; Aug. 5, DDT and acaricide; Aug. 24, DDT and sulphur.
C, June 3 and Aug. 24, sulphur.

greater area traversed to find prey would increase the hazards of cannibalism and of contact with other predators.

The minimum density of the European red mite required to sustain a population of *S. punctillum* in the orchards could not be calculated accurately because of the limitations of the sampling. Despite a strong tendency to disperse, the mites were never uniformly distributed and some parts of the trees always bore populations much greater than the average, especially in the spring and at low densities. Another difficulty was the violent fluctuations in their numbers, which frequently increased more than 10 times in the two-week interval between counts. The population values given below are therefore only rough approximations. The average minimum density of the European red mite capable of sustaining a population of adults of *S. punctillum* was at least 1 per leaf. Even at values considerably above this, very few larvae reached maturity and the population was apparently maintained almost entirely by the egg production of the over-wintered adults. When these dispersed or died, the population frequently died out, or was maintained at a very low level by the influx of other females. An example of the early decrease in numbers of adults is given in Table VI. Although the numbers obtained by jarring on June 1 are not strictly comparable with the later numbers obtained by brushing because jarring is more

efficient, they were definitely much greater at the first date than at the next two samplings. Appreciable multiplication of *S. punctillum* as indicated by the presence of pupae seldom occurred before the mites reached 10 per leaf. Probably the adults, because of their greater mobility, can find local concentrations of mites and so survive and oviposit when the average density of prey is too low for maturation of the larvae.

Examples of the effect of host density on the abundance of *S. punctillum* are shown in Tables VI and VII. In orchard S (Table VII) plots A and B received two August sprays of DDT annually since 1946, so that these plots were repopulated each year by an influx of adults of *S. punctillum*, to some extent in late fall but chiefly in the spring. The mites in plot B were kept at a lower level by an acaricide in one of the DDT sprays. Further details of the spray treatments are given in the tables. It is evident that large populations of *Stethorus* developed only where mites were abundant, the best example being orchard S in 1948, where the three adjacent 100-tree plots bore widely different infestations of mites. In plot A the mites were very abundant until past mid August, and *S. punctillum* reached the highest density found in the experimental orchards over a 7-year period. In plot C the early mite population was very low early in the season and remained so throughout the season; *S. punctillum* was unable to multiply and the population nearly died out, although some repopulation late in the season was indicated by other records. In plot B the mite population was intermediate between those for A and C; *S. punctillum* built up considerably but much more slowly than in A.

When a heavy infestation of the European red mite underwent its characteristic sudden decline in late August, *S. punctillum* also decreased, so that breeding nearly or quite stopped, although some adults usually remained. This decrease was noted especially on unsprayed blocks of plums where high densities of both predator and prey were attained. In the examples given in Tables VI and VII this natural decline was obscured by spray applications of DDT or sulphur; the direct effect of sulphur on *S. punctillum* is still obscure, but high-pressure spraying with water alone dislodges most of the larvae.

When the numbers of prey of a dense population of *S. punctillum* fall abruptly, competition must be an important factor in hastening the decline of the latter. Intraspecific competition would reduce the already limited food supply and promote cannibalism; interspecific competition, if other predators were present, would similarly reduce the prey and increase the chances of destruction of *S. punctillum* by more aggressive predators such as chrysopid larvae. The most important local competitors of *S. punctillum* were *Typhlodromus* spp., where they were not reduced by pesticides. They can apparently survive at a lower host density and usually persisted in considerable numbers after *S. punctillum* had practically disappeared.

Other Factors.—It was mentioned previously that *S. punctillum* could not survive on the scarlet runner bean because the hooked trichomes tear the insect's integument. Similar trichomes are even more abundant on the common bean. With these exceptions the host plants of its prey did not have any obvious effect on *S. punctillum.*

Cultivation of orchards and surrounding land in late fall or early spring must destroy many hibernating adults.

A general idea of the natural mortality during the developmental period was gained by comparing the total numbers of eggs, larvae, and pupae found throughout the season in a number of peach plots that were not disturbed by

pesticide sprays during the periods when *S. punctillum* was abundant and that supported moderate to heavy infestations of mites. The numbers per sample were first adjusted to a uniform basis of 100 leaves and then summed. The chances of finding an individual in a particular stage were approximately proportional to the length of time spent in that stage; therefore the sum for each stage was divided by the duration (Table I) to give figures more nearly expressing the relative abundance of the stages: egg, 18.28; larva, 3.68; pupa, 1.53. For each 18.28 eggs, 1.53 insects reached the pupal stage, a survival of 8.4 per cent. This value is subject to many sources of error but it demonstrates the comparatively low survival rate of *Stethorus* even where prey is relatively abundant.

Importance of *S. punctillum* in Mite Control

The practical value of *S. punctillum* in the control of infestations of the European red mite is strictly limited by its dependence on high density of its prey. Unless the first generation of mites hatching from winter eggs is exceedingly great, they seldom attain numbers sufficient to sustain an increase in numbers of *S. punctillum* until some time in July; they reach maximum density some time in August and drop abruptly to a level usually too low to permit appreciable breeding of *S. punctillum.* The foliage of their hosts may be seriously injured a considerable time before mites reach their maximum numbers. There is thus a period of only 4 to 8 weeks in which *S. punctillum* can multiply freely, and it is quite unable to overtake the rapidly mounting mite population within that time. Not more than two generations can be produced, for adults maturing after early August do not oviposit. Collyer (1953a) found that the relationship of *S. punctillum* to the European red mite was very similar in England.

Although *S. punctillum* cannot bring heavy infestations of the European red mite under economic control, it can reduce the rate of increase and delay the appearance of injury. The adults attack the immature mites of the first generation concentrated on the older leaves, and they and the larvae continue to feed on the mites throughout the season. From data previously given on mite consumption and duration of the larval period, it can be calculated that a larva has a potential average capacity of 20.6 two-spotted spider mites per day and a probable minimum capacity of about 10 per day within an average summer temperature range of 20 to 21.9° C. These figures are generally applicable to the European red mite. A comparatively small population of *S. punctillum* can therefore destroy considerable numbers of mites. This potential rate of predation could not be used to determine the portion of the mite population destroyed by orchard populations of larvae of *S. punctillum* because a disproportionate number of the latter were in the early instars. Also, large but unknown numbers of mite eggs were always present.

In autumn, the adults and those larvae still present feed extensively on the overwintering eggs of the European red mite. Table VII presents the numbers of eggs found in experimental orchard S in December, 1946 to 1948. Some of the non-living eggs were hatched summer eggs, which are occasionally laid on the twigs, and also winter eggs of the previous year, but most were those destroyed by predators; *S. punctillum* was most important although small numbers of *Haplothrips faurei* Hood and a very few of *Typhlodromus* spp. were also active. The numbers destroyed by *S. punctillum* must have actually been higher than was revealed by the counts because the adults eat many eggs completely. Predation was always distinctly heavier in the check plot, C, although some *S. punctillum* also entered the DDT plots late in the season.

TABLE VIII
Average Numbers of Eggs of the European Red Mite per 3 In. of Year-Old Twig in Peach Orchard S in December, 1946–48.

Plot	Spray treatment*	1946		1947		1948	
		Total	Per cent living	Total	Per cent living	Total	Per cent living
A	DDT	285.0	86.0	179.5	59.1	226.3	48.4
B	DDT and acaricide	7.3	84.9	139.5	62.4	196.8	48.6
C	Check	68.0	61.8	78.0	53.4	138.8	3.2

*Details in Table VII; treatment in 1946 similar to that in 1947 except that dicyclohexylamine salt of dinitro-*o*-cyclohexylphenol was used as acaricide in plot B.

The unusual extent of egg destruction in 1948, when apparently only 3.2 per cent of the eggs in plot C were viable by December, was due largely to late-season immigration of adults of *S. punctillum* from neighbouring orchards where they had developed on a heavy mite infestation. Many entered plot C, where breeding had been practically nil until late in the season, but in plots A and B DDT residues destroyed most of the immigrants. On October 7, jarring yielded 4 adults in A, 2 adults and 2 larvae in B, and 48 adults and 3 larvae in C; on October 26, 6 adults were obtained in C and none in the other plots. Extensive predation by *S. punctillum* on the winter eggs was also observed for several seasons in a sour cherry orchard.

There are some indications that the two-spotted spider mite is more susceptible to predation by *S. punctillum* than the European red mite. In the experimental orchards the two-spotted mite did not appear in any numbers until they had been sprayed with DDT for several years and the over-all populations of *S. punctillum* in their vicinities had been greatly reduced; hence information on their relationships was based chiefly on observations in other orchards.

In those peach orchards where the two-spotted spider mite occurs, the overwintered females ascend the trunks and establish breeding colonies on the nearest expanding leaves, usually on shoots from main branches. There dense populations may build up, and not until much later, if at all, do the mites become generally distributed over the trees. These dense localized populations are particularly susceptible to attacks by predators. In an orchard near Grimsby in 1949, *S. punctillum* bred in considerable numbers on such an infestation and apparently eliminated it; many pupae were present by June 13, 2 weeks before they were noticed on foliage infested with the European red mite.

To conclude, *S. punctillum* is an important member of the biological complex that, if undisturbed, limits the population of a number of tetranychid mites. Its powers of dispersal enable it to find local accumulations of prey, but at present are more likely to bring it in contact with toxic spray residues.

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Summary

S. punctillum is a Palaearctic species that has largely replaced the native species *S. punctum* in the Niagara Peninsula, Ontario, within the past 20 years. The adults hibernate near or in the soil, sometimes with little or no cover, but do not survive the winter on the trees. They emerge from hibernation in April and May and begin to oviposit in late May. There are three generations per year, the adults of successive ones beginning to mature in late June, mid July, and early August. Females of the first two generations maturing before early August oviposit during the same summer and usually during the following one; those maturing after early August, irrespective of generation, do not reproduce during the same season but do so during the following one or two seasons. Females that once begin to oviposit may continue until late September or October, but most cease some time after midsummer and enter diapause, from which they are released only after emergence from hibernation the following spring. The greatest number of eggs laid by a female under outside conditions in one season was 845, and over two seasons, 1,290. At 21.1° C. the durations of the immature stages were: egg, 4.7 days; larva, 10.25 days; pupa, 5.2 days.

The larvae and adults attacked all stages of the European red mite and the two-spotted spider mite, but usually refused the clover mite. Seven larvae consumed an average of 239 two-spotted spider mites during their developmental period. Ovipositing females ate a daily average of 40, and males 20 of these mites.

Larvae did not survive long on other foods, but adults lived for several weeks on aphids, raisins, or the sugar-containing secretion of the foliar glands of peach. Eggs were laid only by females that fed on mites.

Adults of *S. punctillum* cannot oviposit nor can the larvae reach maturity unless they encounter their prey at a certain frequency. With the European red mite, which disperses widely over the foliage, this frequency is not attained until the mite has reached an incipient outbreak stage, and the host plant is usually seriously injured before *S. punctillum* can reduce the population. Under special conditions, such as an influx of the predator from another source, it may be of more value. The two-spotted spider mite is more colonial and hence more susceptible to attack. Although *S. punctillum* alone cannot controle severe infestations of mites it is an important member of the biological complex that limits mite populations.

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A Nest of *Heriades variolosus* (Cress.); (Hymenoptera: Megachilidae)[1]

By ROLAND L. FISCHER
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In working on the biology of *Hoplitis producta* (Cress.) and going through a large number of nests of that species, one nest was discovered which was quite distinct from the others. At first, it was thought that this nest was perhaps the nest of another species of *Hoplitis*; however, the subsequent rearing of the bees and their identification has shown the nest to belong to *Heriades* (*Neotrypetes*) *variolosus variolosus* (Cresson). This is the first record of the nesting habit of any member of the subgenus *Neotrypetes*, and while the record is far from complete, it seems that for sake of a more complete picture on the nesting habits of the Megachilidae that it be reported at the time. Rau (1) has recorded the emergence of two individuals of *Heriades* (*Physostetha*) *carinata* Cresson from a hollowed out stem of sumach, but gave no details on the nest construction.

The nest of *H. variolosus* was collected by the author on August 10, 1952, near Ogilvie in Kanabec County, Minnesota. The nest (figure 1A) consists of a hollowed out tubular hole in a dead twig of smooth sumach, *Rhus glabra* L. As is common with other members of the family, the nest consists of a series of cells arranged in a linear fashion to conform with the tubular hole, one above the other. Separating the cells are intercellular partitions composed of extraneous materials brought in from the outside by the maker of the nest.

The total length of the tunnel is 75 mm. The tunnel bore diameter is three mm., the diameter of the pith being only slightly larger, so that the greater bulk of the pith has been excavated to form the tunnel proper of the nest. Five cells comprise the nest, averaging 8.5 mm. in length, with a one mm. cap between

[1]Journal article No. 1673 from the Michigan Agricultural Experiment Station.

each cell. Above the row of cells is found a nine mm. air space, a feature commonly found in the nests of *Hoplitis producta.* Above the air space is found a 27 mm. entranceway. No nest plug was evident at the entrance of the nest, although it is quite possible that the nest had not been completed by the mother bee at the time the nest was collected.

It is difficult, with only the nest at hand, to determine whether or not the mother *Heriades* was responsible for the actual excavation of the nest and did not appropriate it from some other bee or wasp. The newness of the excavations strongly suggest, however, that she was solely responsible for excavating the tunnel or, if not, that she appropriated the nest from some very recent excavator or possibly did a very thorough house-cleaning and re-excavation of the tunnel sides after taking over the nest from its previous inhabitants. If we may again refer to *Hoplitis*, the nearest relative of *Heriades* of whose biology and nesting habits something is known, we note that the female of *Hoplitis producta* almost invariably excavates its own bureau. Thus, the evidence would seem to indicate that *Heriades* also constructed her own burrow.

The cap support (figures 1B and 1C) is a unique feature of the nest. The cap support extends downward along the sides of the tunnel below each cap for a short distance, but does not extend inwardly across the diameter of the tunnel. The support is composed apparently of a salivary secretion which has a marked resemblance to crinkled cellophane, being quite similar in appearance and texture to the material with which the rather remotely related bee genera *Colletes* and *Hylaeus* line their tunnels. The cap support appears to function as a supporting device for the capping material proper. The texture of the material composing the cap support is quite unlike that forming the cocoon spun by the larva. The position of the cap support directly beneath the capping, and the dissimilarity in the texture of the materials in the cocoon and the capping support would indicate that this material is laid down by the mother bee with the completion of the cell to serve as a support for the capping. The formation of the capping support by the mother *Heriades* is apparently a unique feature among the megachilids. The tunnel itself, with the exception of the entranceway down to the cap of the airspace, is partially covered with a salivary secretion. This lining, however, is not of a continuous nature but appears to be mixed, here and there, with the large cells comprising the pith of the stem.

The cap of each cell is composed of two distinct areas (figure 1C). The outer ring consists of a thin layer of soil mixed with very fine sand. The inner circle of the cap is composed of a yellow-brown resin which is quite lumpy, perhaps indicative of the several trips required of the mother bee to collect and construct the cell cap.

After the nest was collected, the nest (Number 143) was stored in an outside insectary where it was subject to the rigors of the weather. The nest was first examined on April 7, 1953, at which time the cocoons had been formed. The cocoons again resembled cellophane, though clouded, and imbedded in the matrix of the cocoon were a great number of whitish silken fibrous strands. It was difficult to observe the stage of the bees closely at this time due to the opacity of the cocoon, and it was deemed best not to disturb them for fear that they would not complete their development and the maker of this unusual nest would remain unknown. On June 9, 1953, a female chewed her way out the side of the cocoon of cell III. No other bees subsequently emerged, with the exception of the occupant of cell I which had previously escaped. Later examination revealed that cell II contained a fully developed dead male, and IV and V dead females.

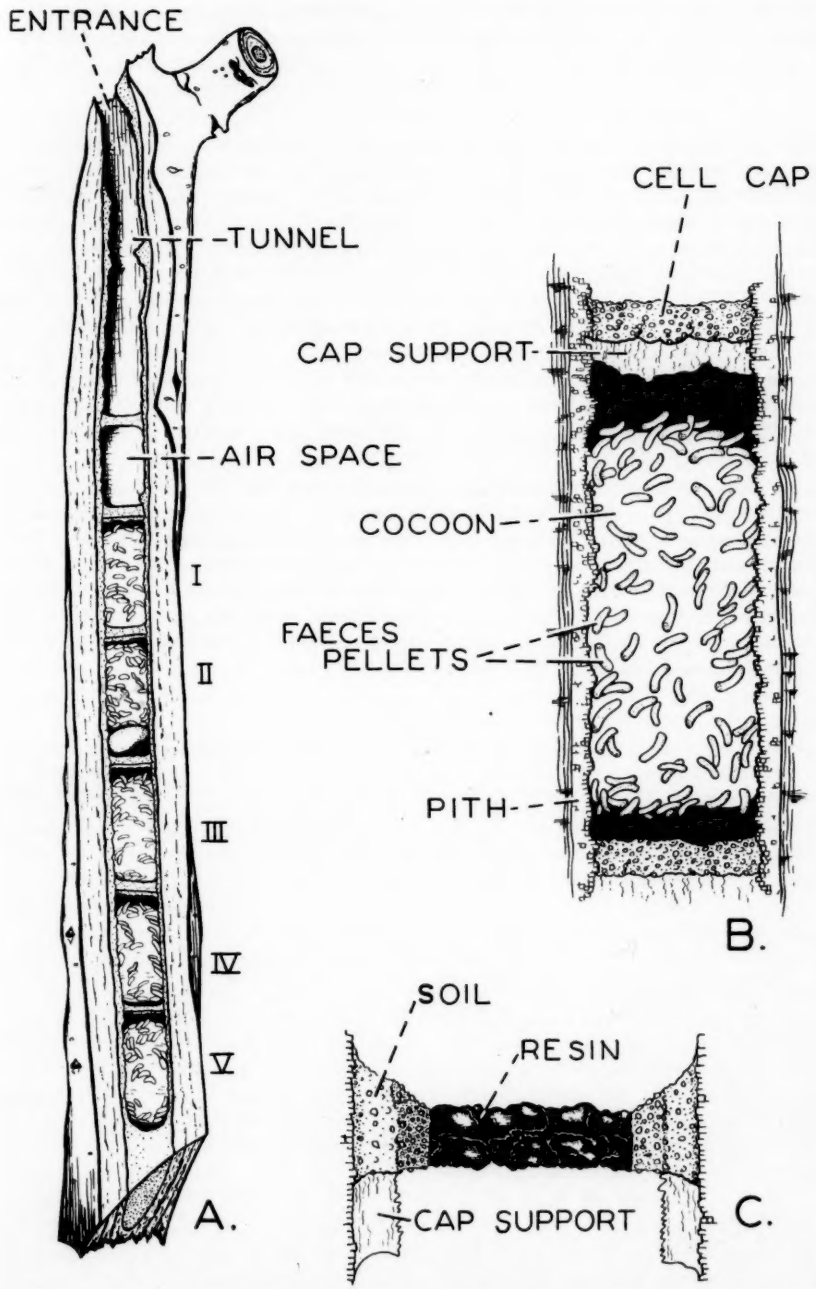

Fig. 1. A. Longitudinal view of the entire nest of *Heriades variolosus* (Cress.). B. An enlarged view of one of the cells. C. A cross-section through a cell cap illustrating the details in its construction (greatly enlarged).

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One other distinct feature of the nest is the helter-skelter arrangement of the faeces pellets on the outside of the cocoon (figure 1B). By contrast, the faeces pellets of *Hoplitis producta* are arranged in a very distinctive pattern, forming a sort of corona at the top of the cocoon just beneath the cell cap.

Since *Hoplitis* is the nearest relative of *Heriades* whose biology is known it may be well to point out the similarities and differences in their nest construction. Both genera have the distinctive air space above the row of cells which make up the nest proper, a cocoon composed of materials resembling cellophane imbedded with silken fibres, and both lack the nipple like projection at the top of the cocoon which has been reported in many of the megachilids. While both genera employ cell caps, the materials in their construction are not the same. *Heriades variolosus* uses an outer ring of soil mixed with very fine sand and an inner ring of resin. The cell caps of *Hoplitis* are quite variable, though apparently specific for the various subgenera and species. *Hoplitis producta* uses chewed up leaves frequently mixed with soil or small pebbles, *H. hypocrita* according to Hicks (2) and Michener (3), of loose uncemented particles of pith, and *H. cylindrica* according to Hicks, fine particles of pith cemented together to form a hard compact mass.

Hoplitis producta closes the entrance of the nest with an additional nest plug which is lacking in the nest of *Heriades* described, although this may be open to some speculation since the nest may have been collected before the *Heriades* female was entirely through with her nest building activities. The tunnel lining and the cap supports are unique features found in the nest of *Heriades*. The last distinctive feature is the arrangement of the faeces pellets, in *Heriades* indiscriminately about the outside of the cocoon and in *Hoplitis producta* about the top of the cocoon in the form of a corona.

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A Description of the Full-grown Larva of *Hylobius radicis* Buch. (Coleoptera: Curculionidae)[1]

By W. Y. Watson
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This description is based on an examination of 25 larvae of *Hylobius radicis* Buch. recovered from the damaged root-collars of dead and dying Scots pine, *Pinus sylvestris* L., in the vicinity of Angus, Ontario. Since larvae of at least one species of the genus *Pissodes* (*P. approximatus* Hopk.) may be found in the same trees, I am also taking this opportunity to compare the external structures of the larva of *H. radicis* with those of the genus *Pissodes* (see Böving, 1929; Anderson, 1947). Where possible, and particularly in the description of the head capsule and mouth parts, the terminology used is that of Anderson.

The larva is white, with an amber-brown head capsule and a duller pronotal shield. The length of the full-grown larva is 14 to 17 mm. and the width of the head capsule is 2 to 2.5 mm. When alive the larva is falciform.

The head (Fig. 1) is free, as wide as long, widest at the middle, with the sides slightly converging below the middle, and above the middle it rounds to a connate and narrowly emarginate apex. The amber-brown capsule has a darker, incomplete frontal endocarina. A narrow epicranial suture extends below the mid-point of the head and bifurcates into the slightly bisinuate epicranial arms, which end dorso-laterally to the antennae. There are five pairs of dorsal epicranial setae: 1 and 2 at the widest point of the capsule, with 2 more dorsad than 1; 3 long, anterior to 1, and near the epicranial arm; 4 quite short, laterad of 3; and 5 long, anterior to and laterad of 4. The two pairs of lateral epicranial setae are long: 1 at the margin of the head in line with the dorsal epicranial seta 4; 2 ventral to the margin of the head just posterior to the antenna. There are five pairs of frontal setae: 1 and 2 short, at the apex of the frons; 3 long, anterior to 2, and separated from it by twice the distance from 1 to 2; 4 much shorter than 3, and closely laterad of it; and 5 long, near the margin of the capsule at the base of the catapophysis. Of the ventral setae, 1 is longer than 2 and is more mediad, 2 is just ventral to the antenna. The head capsule also bears several sensory setae: three pairs on the epicranium, the most dorsal pair being mediad of the other two; one single seta on each side between the frontal setae 1 and 2; and a second single seta between 3 and 4.

The clypeus bears, at the posterior margin, two pairs of setae. They are short and may, in some specimens, be blunt.

Dorsally, the labrum (Fig. 2) has two pairs of setae. These are long, nearly straight, and situated in the basal half of the sclerite. The members of the outer pair (number 3 of Anderson) are more than twice as far from the inner pair (number 1 of Anderson) as the members of this pair are from each other. The epipharynx has three pairs of antero-lateral setae. These are short and peg-like and are arranged in a shallow arc. Two pairs of antero-median setae are also present, the outer pair more than half the length of the inner pair. Of the two pairs of median spines occurring on the epipharynx, the posterior pair is slightly longer. A pair of sensory pores lies between the pairs of spines.

The mandibles (Fig. 3a) are thick, conical structures, with four poorly-defined teeth along the inner edge. The apical tooth is narrow and elongate, the second is shorter and more flatly conical. Posteriorly from it, there extends an arcuate crest, which terminates as a short third tooth. At its base is a minute

1Contribution No. 186, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

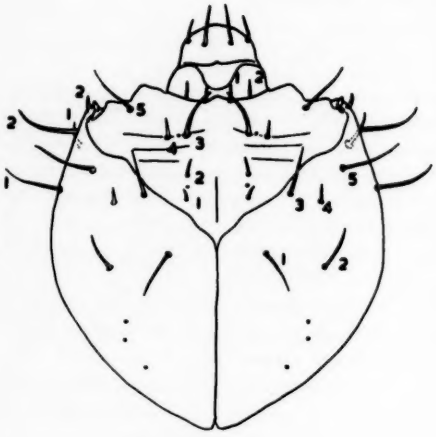


Fig. 1

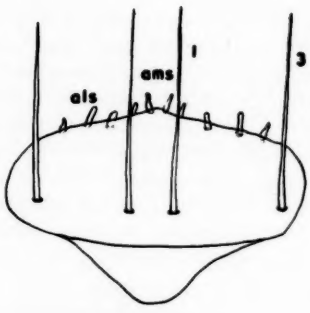
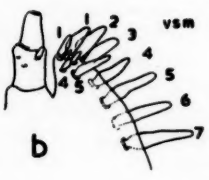


Fig. 2



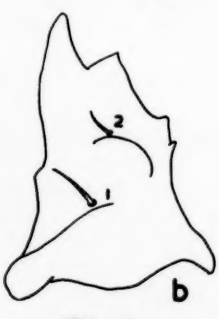


Fig. 3

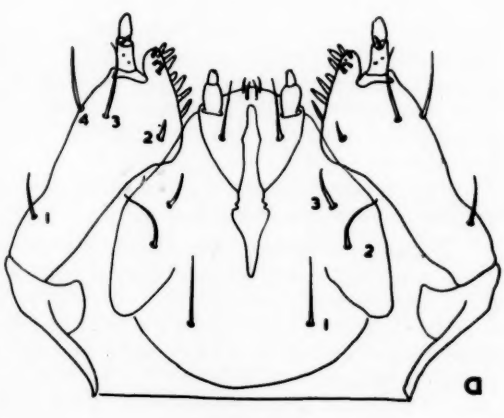


Fig. 4

Figs. 1 to 4. 1. Dorsal view of head capsule with mandibles removed. (X19). 2. Dorsal view of labrum: ams, antero-median setae; als, antero-lateral setae. (X43). 3. Mandible: a, buccal surface; b, lateral surface. (X36). 4. Maxillae and labium: a, ventral view, (X36); b, ventral aspect of mala and maxillary palpus. (X60).

fourth one. On the outer face of the mandible (Fig. 3b) are two setae; 1 is longer and more lateral than 2.

The maxillae (Fig. 4a) are large and lightly pigmented. The stipes is broader at the apex than at the base and is sinuate on the outer margin. There are four setae on the stipes: 1 moderately long, at the base of the stipes; 2 very short, at the base of the mala; 3 and 4 long, at the base of the palpus near the lateral margin. The mala (Fig. 4b) bears five ventral and seven dorsal teeth. Of the five ventral teeth, 1 is long and blunt; 2 very short and pointed; 3 slightly longer and blunt; and 4 and 5 in a second row immediately posterior to 3, with 4 as short as 3 and blunt, and with 5 longer than 1 and tapering. The maxillary palpus has two segments: the basal segment is cylindrical and bears a short spine and two sensory setae near the distal margin; the apical segment is bluntly conical and bears minute sensory setae at the apex.

The labium (Fig. 4a) is composed of a large postmentum and a smaller prementum. On the postmentum are three pairs of setae: 1 long and straight; 2 long and curved more lateral and anterior to 1; and 3 short and straight, anterior to and mediad of 2, separated from 2 by half the distance from 1 to 2. On the prementum is a single pair of setae, one at the base of each palpus. Between the palpi are two pairs of very short setae. The palpi have two segments, the basal is larger and swollen, the apical, short, conical, and truncate.

Each segment of the thorax (Fig. 5) has two lobes dorsally. Those of the prothorax are long and flat, whereas those of the meso- and metathorax are more truly lobes. The posterior lobe of the prothorax is provided with a medially-divided shield that bears seven setae on each side, the one on the posterior edge being the longest. This lobe in the mesothorax bears four dorsal setae on each half, positioned in a group of three, with a single, longer seta set off more postero-ventrally. The metathorax is similar except that the setal group of three is more transverse.

On the prothorax, just ventral to the shield and above the spiracle, are two short setae. Below the spiracle and anterior to it are two setae, the anterior one being the longer. Six setae are present on each pedal lobe, five short and one usually twice as long as the others. On the sternum is a pair of very short setae.

Ventral to the four dorsal setae on the mesothorax is a single seta above the level of the prothoracic spiracle. A lobe of the mesothorax, just below and behind the prothoracic spiracle, bears two short, widely-spaced setae. Below this again is a single, long seta. The pedal lobes and the sternum are similar to the prothorax. The metathorax has a group of three short setae in a vertical line on the subspiracular lobe, two close together and one distant.

The first seven segments of the abdomen are alike (Fig. 6). Each has three dorsal lobes, the first of which bears two short setae on each side. The second lobe is naked, and the third bears a transverse row of six shortened setae on each side. Above and posterior to the spiracle is a single, short seta. Ventral to the spiracle is a lobe with two setae, the upper only one-half the length of the lower. Ventral to this is a lobe bearing two setae set horizontally, the posterior seta being twice as long as the anterior. The pedal lobe, which is much less pronounced than those of the thoracic segments, bears a single short seta. The sternum has two very short setae on each side (Fig. 9).

The eighth and ninth segments (Fig. 7) have single dorsal lobes that are rather long and flat. The dorsal setae are reduced to two, the more lateral being the longer. On the eighth segment, the spiracle is more dorsal than on segments I-VII. Below and just posterior to the spiracles is a lobe with two

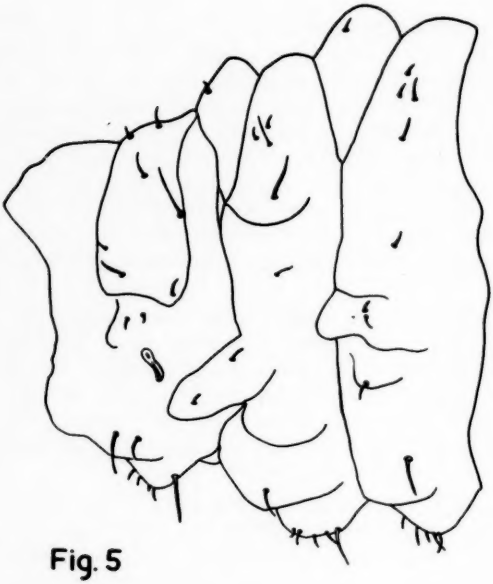


Fig. 5

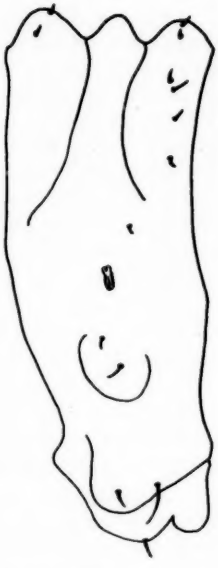


Fig. 6

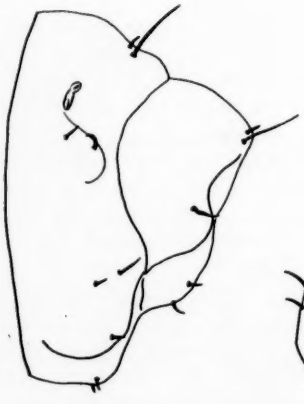


Fig. 7

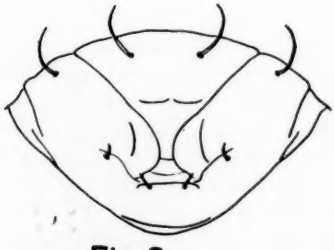


Fig. 8

Fig. 9

Figs. 5 to 9. 5. Lateral view of thorax. (X20). 6. Lateral view of third abdominal segment. (X20). 7. Lateral view of eighth and ninth abdominal segments. (X20). 8. Posterior view of abdomen showing setae of ninth segment. (X20). 9. Ventral view of third abdominal segment. (X20).

subequal setae. Much ventral to this are two setae, the posterior one being the longer. Ventrally there is a single short seta. The pedal seta is short as are the two sternal setae on either side. The ninth segment has on each half, a single long seta dorsally, another laterally, and a row of five short setae along the posterior ventral margin (Fig. 8).

The spiracles are alike on the thorax and the abdomen. They are elongate and bicameral. The air tubes have incomplete annulations and are twice as long as the short diameter of the oval peritreme.

Using the details given above for *Hylobius radicis* and those given in part by Anderson for the genus *Pissodes*, the following points of comparison may be noted:

	H. radicis	*Pissodes* spp.
1.	Length from 14 to 17 mm.	Length rarely exceeding 9.5 mm.
2.	Labrum with two pairs of setae.	Labrum with three pairs of setae.
3.	Epipharynx with outer antero-median pair of setae half the length of the inner.	Epipharynx with the outer antero-median pair of setae minute.
4.	Malar setae blunt.	Malar setae sharp.
5.	Malar setae 1, 2, 3, broad at base and swollen on one side.	Malar setae 1, 2, 3, evenly tapering.
6.	Pronotal shield well marked.	Pronotal shield ill-defined or absent.
7.	Dorsal thoracic setae few.	Dorsal thoracic setae numerous.
8.	No mid-ventral sclerotized area.	Mid-ventral sclerotized area present on prothorax.
9.	Ninth segment with the number of setae reduced.	Ninth segment with the number of setae as in other segments.
10.	Spiracles elongate, peritreme oval.	Spiracles short, peritreme round.

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(Received December 1, 1954)

Notes on Life Histories of Some Ennominae (Lepidoptera, Geometridae)[1]

By W. C. McGuffin[2]

Introduction

The life histories of many of the Geometridae are not well known; those of a few economic species in the Ennominae have been worked out but many more remain to be studied. Life-history notes on the following seven species are presented: *Semiothisa granitata* Gn., *S. sexmaculata* Pack., *Eufidonia discospilata* Wlk., *Melanolophia canadaria* Gn., *Campaea perlata* Gn., *Selenia alciphearia* Wlk., and *Caripeta divisata* Wlk. The larvae of all these have been described; those of *Selenia* and *Campaea* were described by Dyar (1899 and 1903) and the remainder by McGuffin (1943a, 1943b, 1944, 1945, and 1947).

Material and Methods

The material for these life histories was secured in three ways:

(1) adults were reared from larvae received in Forest Insect Survey collections; these adults mated and oviposited (*Semiothisa*, *Caripeta*);

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(2) eggs received by the Survey were incubated (*Campaea, Selenia*);
(3) gravid females were collected (*Melanolophia, Eufidonia*).

In most cases the larvae were reared individually in 20 to 25 millilitre screw-top vials. These were maintained at room temperature. The larvae in the vials were examined daily and the head capsules were measured after each moult. In the last instar the width of the head itself was measured.

Life Histories

Semiothisa granitata Gn.

In the laboratory, oviposition takes place about 11 days after the moths have been caged. A female may lay as many as 60 eggs over a period of two days. After an incubation period of six or seven days, the larvae hatch; these larvae which have been described by the writer (1943a) feed on spruce (*Picea* spp.), pine (*Pinus* spp.), larch (*Larix* spp.), hemlock (*Tsuga* spp.), fir (*Abies* spp.), and Douglas fir (*Pseudotsuga taxifolia* (Poir.) Britton). They moult five, or occasionally six, times in from 36 to 55 days. In nature this species hibernates in the pupal stage but when reared in the laboratory, adults may be obtained without exposing the pupae to freezing temperatures. The moths fly during June and July in New York (Forbes, 1948) and Alberta (Bowman, 1951) and from May to August in British Columbia (Jones, 1951).

Semiothisa sexmaculata Pack.

Moths of this species lay eggs five or six days after caging the two sexes together. Eclosion takes place in from 11 to 12 days after oviposition. The larvae, described by the writer in 1947, feed on species of larch (*Larix* spp.); they develop after five instars to the pupal stage in from 31 to 38 days. The species may pupate and emerge in one season in Eastern Canada and British Columbia but the majority in these regions and almost all those in the Prairie Provinces hibernate in the pupal stage. The flight period is from May to early July.

Eufidonia discospilata Wlk.

In 1946 a gravid female of this species was collected in the Whiteshell Forest Reserve, Manitoba. It was flying over a boggy area near Brereton Lake. The conspicuous plants of the bog carpet were Labrador tea (*Ledum groenlandicum* Oeder) and sheep laurel (*Kalmia angustifolia* L.). When caged with foliage of these two plants the moth laid all the eggs, 30 in number, on the wool of the branches and undersides of the leaves of Labrador tea. The eggs hatched on June 24 and the larvae, described by the writer (1945), passed through five instars; the larvae were offered and fed on sheep laurel, Labrador tea, blueberry (*Vaccinium* sp.), cherry (*Prunus* sp.), and jack pine (*Pinus banksiana* Lamb.). It is of interest that this species fed sparingly on jack pine yet the closely related species, *E. notataria* Wlk., a conifer feeder, is frequently collected from jack pine in many parts of the host plant range. Hibernation is in the pupal stage and the adults fly in June.

Melanolophia canadaria Gn.

A moth captured at Winnipeg on the evening of June 12, 1946, laid eggs the next morning. From these eggs ten larvae hatched on June 25. They were offered hazel (*Corylus* sp.), cherry (*Prunus* sp.), white elm (*Ulmus americana* L.), and bur oak (*Quercus macrocarpa* Michx.). The larvae fed on all of these, eating holes in the leaves of hazel and patches from the lower surface of leaves of the other trees. Those reared on elm developed a dorsal pattern of reddish crosses; these markings were not observed on larvae fed on oak, hazel or cherry.

(Other food-plants of this species are red maple (*Acer rubrum* L.), staghorn sumac (*Rhus typhina* L.), rock elm (*Ulmus thomasi* Sarg.), white birch (*Betula alba* L.), yellow birch (*B. lutea* Michx. f.) and possibly balsam fir (*Abies balsamea* (L.) Mill.). There are five larval instars; descriptions of the larvae have been published by McDunnough (1933) and McGuffin (1944). Pupation takes place in the late summer and the adults emerge in the spring.

Campaea perlata Gn.

Dyar (1903) described the egg and five larval stages of this species. The eggs hatch after 11 days incubation. On August 7, 1952, the writer found a mass of eggs, 38 in number, which had been laid in a single layer on the underside of a leaf of buffalo berry (*Shepherdia canadensis* (L.) Nutt.) near Seebe, Alberta. Larvae hatched August 9 and fed until early October. They ceased feeding in the third and fourth instars and were buried in the ground in vials. Unfortunately the larvae died during the winter but normally they resume feeding again in the spring as soon as the leaf buds of the food plants (nearly all the common angiosperm trees and shrubs and a few conifers) have opened. The species pupates during June and July and the moths emerge about 20 days after pupation. In contrast with this, Dyar (1903) noted that one specimen emerged the same season but that most of the individuals hibernated in the pupal stage.

Selenia alciphearia Wlk.

The egg and all five larval instars of this insect were described by Dyar (1899). Dyar records that eggs sent to him from Vermont hatched early in June. In Alberta, eggs collected at Alexo, west of Rocky Mountain House, hatched June 21 and 22 in 1953. Although these eggs had been laid on common juniper (*Juniperus communis* L.) the larvae did not feed very well on this plant. At the time of eclosion the writer had not identified this insect as *Selenia* and did not know what to feed the larvae. Therefore the plants which often grow near juniper were considered; of these trembling aspen (*Populus tremuloides* Michx.), willow (*Salix* sp.), alder (*Alnus* sp.), shrubby cinquefoil(*Potentilla fruticosa* L.), rose (*Rosa* sp.), buffalo berry (*Shepherdia canadensis* (L.) Nutt.) and wild pea (*Lathyrus* sp.) were offered to the larvae. They fed most readily on aspen, willow and alder; they showed less preference for buffalo berry, rose and cinquefoil and no taste at all for the wild pea. Other plants noted as food of this species are: gooseberry (*Ribes* spp.), raspberry (*Rubus* spp.), maple (*Acer* sp.), white birch (*Betula alba* L.) and high bush cranberry (*Viburnum trilobum* Marsh.). Pupation takes place in August or September and the pupae hibernate. The adults fly in the spring and early summer.

Caripeta divisata Wlk.

When reared in captivity, oviposition takes place from one to four days after caging the two sexes together. A female may lay up to 34 eggs over a period of two or three days. The larvae, which have been described by the writer (1943b) hatch in about 10 or 11 days and feed on coniferous trees, such as spruce (*Picea* spp.), larch (*Larix* spp.), fir (*Abies* spp.), Douglas fir (*Pseudotsuga taxifolia* (Poir.) Britton), and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). The larvae moult six times and pupate in 38 to 53 days. In nature the species hibernates in the pupal stage but in the laboratory adults can be obtained when pupae are kept at room temperature. The moths fly in July east of the Rocky Mountains (Forbes, 1948; Bowman, 1951) and in June, July and August farther west (Jones, 1951).

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Summary

Seven species of the geometrid subfamily Ennominae have been reared from egg to adult; these species are *Semiothisa granitata* Gn., *S. sexmaculata* Pack., *Eufidonia discospilata* Wlk., *Melanolophia canadaria* Gn., *Campaea perlata* Gn., *Selenia alciphearia* Wlk., and *Caripeta divisata* Wlk. In most of these there are five larval instars but in *Caripeta* there are six, and in *Melanolophia* there are seven, instars. All but *Campaea* normally hibernate as pupae but since adults may emerge without hibernation from pupae of *Semiothisa granitata* and *Caripeta divisata*, it would appear that the habit is not obligatory in those species. Moreover some adults of *Semiothisa sexmaculata* occasionally emerge in the same season in Ontario, Quebec, and British Columbia but this rarely occurs in the Prairie Provinces. The species, *Campaea perlata*, overwinters in the larval stage. Stokoe and Stovin (1948) quote Newman's similar observation on the species, *C. margaritata* L., in Great Britain. However, Dyar (1903) noted that *C. perlata* from British Columbia hibernated in the pupal stage.

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A New Species of *Hilara* from Arctic Canada (Diptera: Empidae)[1]

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***Hilara nearctica* n. sp.**

Black, uniformly dark brown- or grey-pollinose. Thorax obscurely quadrivittate. Legs short-haired. Wings milk-white in both sexes.

Head black; frons and occiput, viewed from above, velvety with dark-brown tinge; bristles and hairs fine, black, the former about as long as third antennal segment less style. Antenna black, slightly shorter than head; style about half as long as third segment. Palpus and proboscis black.

Thorax black, covered with dark grey- or brown-reflecting pollen; two darker vittae on interstices between acrosticals and dorsocentrals, ending at prescutellar depression; two broader vittae outside dorsocentral row, abbreviated anteriorly. Bristles black; dorsocentrals short, about as long as diameter of third antennal segment, longer posteriorly, irregularly uniserial or biserial; acrosticals short, irregularly quadriserial, sometimes biserial anteriorly; humeral present, moderately long, fine. Scutellum with four marginal bristles. Legs black, brown- or grey-pollinose; hairs short, those on coxae pale, elsewhere brownish or black, only a short preapical ventral bristle on each femur; anterior metatarsus of male two-thirds as long and about one and a quarter times as wide as its tibia; hind tibia of female slightly swollen in middle, narrowly fusiform. Wing milk-white, semi-opaque; costa and apical enlargement of first vein dark brown; other veins brown, becoming paler posteriorly; pterostigma almost colourless; anterior branch of third vein ending closer to second vein or midway between it and posterior branch. Calypteres dark brown with white fringe. Halteres dark brown to black.

Abdomen concolorous with thorax; dorsum subshining; hairs sparse, white or pale golden. Hypopygium moderately large, not deeper than apex of abdomen; ventral keel not strongly compressed; lateral lamella deeply cleft, its upper margin produced in a slender, parallel-sided spatulate process.

Length of body 3.0-3.5 mm., of wing 3.5-4.2 mm.

Holotype, ♂, Chesterfield, N.W.T., 25.VII.1950, J. G. Chillcott. No. 6169 in the Canadian National Collection, Ottawa.

Allotype, ♀, Wager Bay, N.W.T., 22.VII.1950, J. G. Chillcott.

Paratypes, ♂, Baker Lake, N.W.T., 7.VIII.1947, T. N. Freeman (CNC). 1♂, 3♀♀, Head of Clyde Inlet, Baffin Island, N.W.T., 10-20.VII.1950, V. C. Wynne-Edwards (British Museum (Nat. Hist.)).

Although many species of *Hilara* Mg. occur in the Boreal forest, the genus is evidently rare on the tundra. I know of only one other North American record from an undoubted tundra locality, that of Weber (1954), who lists an unidentified species from Umiat, Alaska. Henriksen (1939) does not list the genus among the empids of Greenland and most of the northern Scandinavian species listed by Ringdahl (1951) are forest species, although a few seem to occur up to and even slightly beyond the tree-line in mountainous districts. *Hilara nearctica* n. sp., on the other hand, appears to be confined to the tundra and has

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not been found among the large collections of Empidae made in recent years at Churchill, Man., and other tree-line localities.

The striking character of milk-white wings is a familiar one in several families of Diptera and, in the Empidae, occurs in some of the smaller species of *Hilara*, *Empis* L., and *Rhamphomyia* Mg. Two such species of *Hilara* have been described from the Nearctic region, namely, *leucoptera* Lw. from Florida, a subshining black species; and *carbonaria* Mel. from New Hampshire, a species with velvet-black thorax. Among the white-winged Palaearctic forms, *H. nearctica* falls closest to the species recognized by Collin (1927) as *galactoptera* Strobl. It differs from it in the more brownish colour, in the pale hairs of the abdomen and legs, and in the form of the lateral lamella of the hypopygium, which, in *galactoptera*, has the upper margin produced in a long slender spur of needlelike sharpness. From *H. ragasides* Frey (1935) it differs in the lack of bristling on the legs, from *albipennis* v. Ros. (=*niveipennis* Zett.) and *galactoptera* Frey (1935; nec Strobl, 1909) in the much darker colour of the body, and from *lacteipennis* Strobl. in the mesonotal pattern and dark halteres.

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Window Flight Traps for Insects[1]

By JOHN A. CHAPMAN AND JAMES M. KINGHORN[2]

During the past spring and summer glass barrier traps have been used as a means of sampling the flying populations of an ambrosia beetle, *Trypodendron* sp., and other scolytid beetles. The "window" trap has functioned well enough to warrant its brief description. A piece of window glass (2 x 2 ft.) is set in a three-sided wooden frame from which a sheet metal trough is hung. The trough is filled with fuel oil or water to which a wetting agent is added. Screened outlets provide for drainage of excess rain water in the latter case and when oil is present an inverted "L" tube drains this water from beneath the oil. Insects are collected by removing the trough and pouring its contents through a strainer. Traps are hung from various types of pole framework depending on their location, and guy wires are used to keep them from swinging.

The traps function because insects flying against the glass frequently drop into the collecting fluid. Wind conditions influence trap performance and the flight behaviour of insects is a significant factor in the effectiveness of their capture. Light-bodied forms such as midges and aphids are not taken efficiently but most Coleoptera and many Hymenoptera, Diptera, Lepidoptera, and other winged insects are frequently captured. Coloured barriers have been substituted for glass but are much less effective for most insects.

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The traps have been used in both logged and timbered areas. Observations of insect flight in relation to traps set in the open indicate that many insects avoid them to some extent, perhaps at times because of reflections but probably mostly because the supporting structures, frames and troughs present a visual obstruction. It is possible that they are more efficient in forest or brush-covered areas where there are other obstacles to flight. Regardless of location, however, the traps take a sufficient sample of many of the insects which are common in an area to permit satisfactory determinations of seasonal abundance, site distribution and relationship of flight to weather conditions. A typical three-day fair-weather collection, (May 7-10) by a pair of the traps set at the 6-foot level in a recently logged area is given to illustrate the numbers of insects taken.

Trypodendron sp.	724	Cleridae	10
Pseudohylesinus spp.	164	Rhizophagidae	9
Hylurgops spp.	150	Buprestidae	1
Dendroctonus pseudotsugae	25	Other Coleoptera	14
Other Scolytidae	17	Diptera	15
Staphylinidae	63	Hemiptera	2
Curculionidae	16	Hymenoptera	1
Elateridae	16	Lepidoptera	1
Cerambycidae	13		

These traps can be simply and inexpensively constructed. They can be set up in a variety of field locations and may be left unattended for many days at a time, with oil as a collecting fluid, so that deterioration of the insects and evaporation are minimized. It should be mentioned, however, that oil, splashed on the glass by wind and rain, reduces its effectiveness as a transparent barrier. The glass remains quite clean when water with added wetting agent is used as a collecting fluid. The traps may be used in conjunction with a light source, as light traps. They may also be made partly directional by covering one half of the collecting trough. By substituting rigid transparent plastic for glass the wooden frame could be eliminated and an unbreakable trap would result which could give service under field conditions for many seasons.

Fourth Annual Meeting of The Entomological Society of Canada

The Entomological Society of Canada held its fourth annual meeting jointly with the ninety-first annual meeting of the Entomological Society of Ontario at the Sault Ste. Marie Armoury, Sault Ste. Marie, on November 1 to 3. A total of 214 members and friends registered, including 25 members and guests from the United States and 22 wives. Dr. R. M. Belyea, Officer-in-Charge, Forest Insect Laboratory, Sault Ste. Marie, welcomed the two societies, and Dr. B. P. Beirne, Acting President, Entomological Society of Ontario, welcomed the Entomological Society of Canada.

Invitation papers were presented during two sessions by four prominent biologists, and a session was devoted to a symposium on approaches to the study of forest insects. Papers of which titles had been submitted were presented at one session of four sections: Insect Physiology, Natural Control and Ecology, Insecticides and Acaricides, and Taxonomy and General Entomology.

An enjoyable open house and tea was held at the Forest Insect Laboratory on the afternoon of October 31, and on the afternoon of November 3, visitors were conducted on highly interesting tours of the Forest Insect Laboratory and the Laboratory of Insect Pathology. On the evening of November 1, a smoker at the Windsor Hotel was much enjoyed through the courtesy of O'Keefe's

Brewing Company, Ltd. On November 2, after a cocktail hour provided by courtesy of the Canadian Wine Institute, a banquet and address were much enjoyed, with S. G. Smith as chairman. A. W. Baker gave entertaining reminiscences and thanked the various organizations to whom the two societies were indebted for enjoyment of facilities. The guest speaker of the evening, Col. H. S. Hamilton, Q.C., Sault Ste. Marie, gave a challenging address on building a better democracy. A total of 190 members and friends attended.

On the afternoon of November 1, the ladies enjoyed tea at the officers' mess at the Sault Ste. Marie Armoury.

At the annual business meeting, on November 3, A. W. Baker reviewed the steps leading up to the possibility that the International Congress of Entomology might meet in Canada in 1956; a brief was being prepared for submission to the Prime Minister of Canada recommending that the Government issue an invitation to the Congress. W. R. Thompson summarized what had been done concerning the publication of papers too long for regular issues of *The Canadian Entomologist*; it was hoped to begin a series of supplements to the journal with a paper from the Forest Biology Division of the Canada Department of Agriculture on the internal anatomy of sawfly larvae. The audited statement of the financial situation for 1953 was supplied by A. B. Baird to all members present. He also supplied an interim statement for 1954, indicating a favourable balance of about $1,300 for the year's operations, and copies of a letter of October 19 to the Board concerning the increase to $9.25 per page for printing 1,100 copies of the journal, an increase of about $2.00 per page. This increase would mean an increase of about $2,000 in total costs, and a probable deficit of about $700 unless income were increased. There were 409 members paid up out of 498 and 277 subscribers paid up out of 280; 97 exchanges, 9 advertisers, and 14 honorary and life members brought the mailing list to a total of 898. A. W. Baker appealed to all present to have their regional societies do everything possible to secure advertising for the journal.

On motion of A. J. Thorsteinson and B. M. McGugan, it was agreed that the President, the Vice-President, and the three directors at large be elected by mail ballot of all the members; on motion of W. A. Reeks and P. W. Reigert, it was agreed that the Board should set up the machinery to put the motion into effect. It was agreed that the Board should name a nominations committee for 1955, for election of officers at the annual meeting in 1956.

R. W. Salt reported the following nominations of the Nominations Committee for officers for the next two years:—President, Rev. O. Fournier; Vice-President, Dr. R. Glen; Editor, Dr. W. R. Thompson; directors at large, Dr. J. Marshall, Dr. A. W. A. Brown, and Mr. W. A. Reeks. All the nominations were approved.

On motion of J. M. Cameron and G. F. Manson, it was agreed that the incoming Board should appoint a committee to review the Constitution, particularly to eliminate apparent contradictions, and to add by-laws, the committee to be appointed at a meeting of the Board to be held at the close of the annual business meeting and the proposed revisions to be mailed to the members for consideration before the next annual meeting.

An invitation received from the Acadian Entomological Society to hold the annual meeting in 1955 at Fredericton, N.B., was referred to the Board.

On motion of W. A. Ross and A. A. Beaulieu, W. A. Fowler and R. W. Martin were re-elected auditors for the year. R. H. WIGMORE, *Secretary*

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